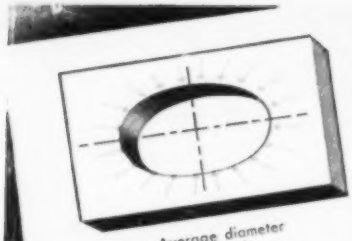
Industrial QUALITY CONTROL

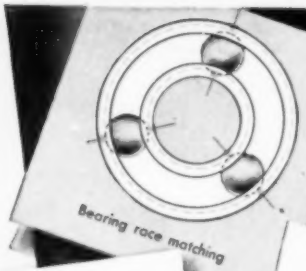
MARCH, 1952 VOL. VIII, NO. 5

The Lot Plot Form in Use—Pitch Diameters Being Tallied

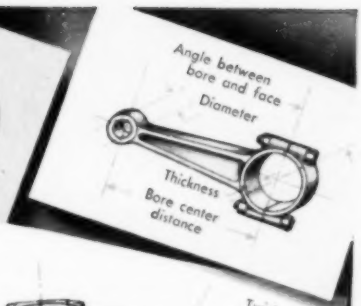
AMERICAN SOCIETY FOR QUALITY CONTROL

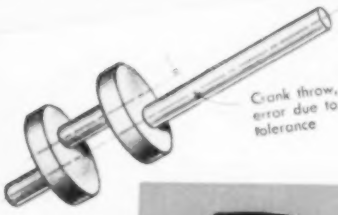


Average diameter of a hole



Bearing race matching





Crank throw, eliminating all error due to diametral tolerance

Lobing or cloverleaf of a centerless ground shaft

Typical Dimensions and Relationships measured with *Sheffield* PRECISIONAIRE GAGES

The range of dimensions and position relationships which can be measured quickly and precisely by Precisionaire Gages is almost limitless. In fact, some such measurements are possible otherwise only by elaborate auxiliary equipment in a well equipped laboratory to obtain the same degree of accuracy. Illustrated here are typical Precisionaire applications in which deviations have been exaggerated for greater clarity.

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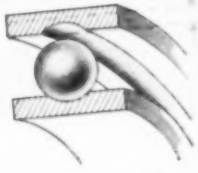
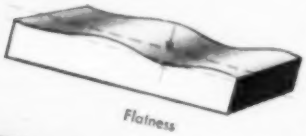
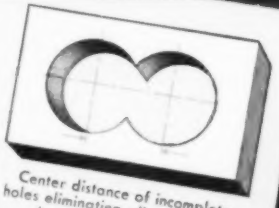


Internal radial clearance



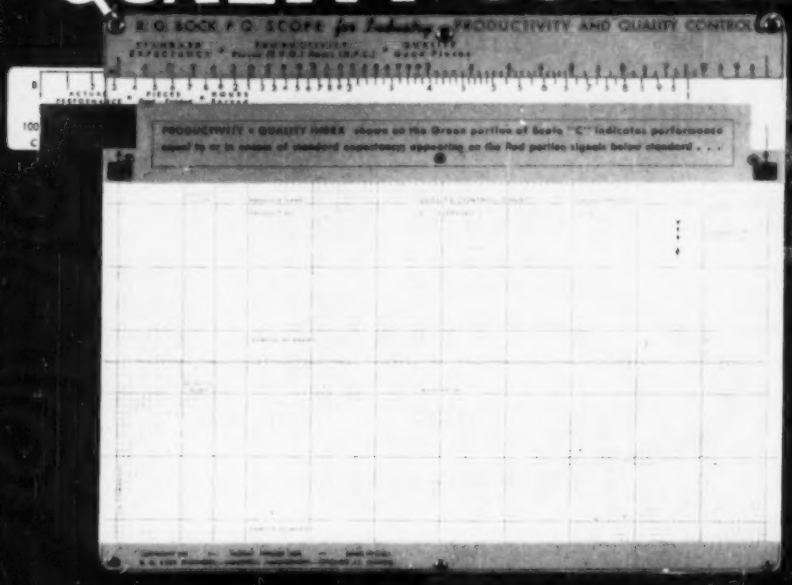
Flatness

Distance between hole centers eliminating all error caused by diametral tolerance



Center distance of incomplete holes eliminating all error caused by diametral tolerance

QUALITY CONTROL



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The **Quality Index**, developed by R. G. Bock Engineers, is a means of rating the quality level of a process wherein upper and lower control limits are established at a 100% and each horizontal line in the dispersion field, between the center line and the upper and lower control limits represents a predetermined increase in value. Plottings within control limits, are stenciled in green — out of control (or below standard performance) in red — showing magnitude of variations. **The Quality Index is adaptable with any type of control chart** and coordinates the control chart with the signal arm — (c).

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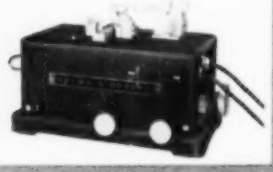
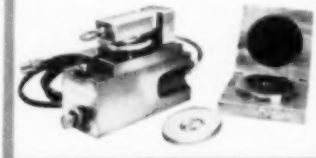
TYPICAL APPLICATIONS

Special gaging fixture made by Brown & Sharpe for inspecting dimensions, side parallelism and side squareness of cutter blades. Employs 4 Gage Head Cartridges . . . used with 4 Amplifiers.



Special gaging fixture, custom-made by Brown & Sharpe, permits gaging of meter valve plate flatness to .00001", when used with Brown & Sharpe Amplifier.



Custom-made fixture, employing Brown & Sharpe Gage Head Cartridge and one Amplifier, measures major and minor I.D.'s of tapered bores; indicates internal angle accuracy.

Brown & Sharpe Gage Head Cartridge and Electronic Amplifier

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MIDDLE ATLANTIC REGIONAL CONFERENCE

The 1952 Middle Atlantic Regional Conference will be held at the Hotel Statler in New York City on Friday and Saturday, March 28-29, 1952.

Full program details may be obtained from

Thomas A. Budne
Chairman, Publicity Committee
E. R. Squibb & Sons
New Brunswick, N. J.

In broad outline, the program consists of twelve panel sessions, three running concurrently in each half-day, and two luncheon sessions. The Friday luncheon session will feature "Quality Control—Its Possibilities", by Wade R. Weaver, President, ASQC. At the Saturday luncheon, Mr. George F. Smith, President of Johnson & Johnson, will speak on "Quality Control—A Management Opportunity".

Each panel session will feature from two to three experienced speakers presenting various phases of the general theme for that particular panel. Panel themes are as follows, in chronological order beginning with Friday morning:

Panel A: *Basic Concepts of Quality Control*
Panel B: *How to Introduce Quality Control*
Panel C: *Small Parts Manufacture*
Panel D: *Vendor Relations with the Armed Forces*
Panel E: *Chemical Process Control*
Panel F: *Statistical Techniques in Research and Development*
Panel G: *Pharmaceutical and Chemical Controls*
Panel H: *Quality Control in the Electronics Industry*
Panel I: *New and Useful Techniques*
Panel J: *Applications to Business Operations*
Panel K: *Administration of Quality Control*
Panel L: *Applications of Statistical Quality Control*

The themes characterizing these twelve panel sessions will be expanded by a total of 26 separate papers handled by a total of 31 individual speakers. A bound copy of papers presented on this program will be available for sale

NOTICE

The films reviewed in the January 1952 issue are available through

Earl J. McGrath, Commissioner
U. S. Office of Education
3rd & Independence Ave., S.W.
Washington 25, D. C.

Industrial Quality Control

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Headquarters Office

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Correspondence is invited on all controversial matters.

General Information

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Direct Subscriptions to INDUSTRIAL QUALITY CONTROL will not be accepted from individuals. However, subscriptions to the magazine will be received from Libraries and like institutions at six dollars per year. Remittances must be in United States funds and should be sent directly to the Secretary of the Society.

Membership in the American Society for Quality Control is available in three grades through local Sections or directly through the Executive Secretary. Annual dues for direct national membership are: for Members, $10.00; for Senior Members, $12.00; for Fellows, $16.00. In each grade, $3.00 of the annual dues are allocated as a subscription to INDUSTRIAL QUALITY CONTROL. The Member grade is open to any person of good character who is 21 years of age and engaged or interested in quality control. Information covering higher grades of membership and concerning local Sections may be obtained from the Executive Secretary.

Membership in the Society is personal and professional, and is not open to corporations, companies, or other organizations.

Contributions to the Society for the support of its activities will be accepted from corporations, companies, and others.

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Inquiries regarding advertising rates, advertising contracts, and advertising space available should be addressed to

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Correspondence concerning membership, dues, institutional subscriptions, requests for back issues, and allied matters should be addressed to

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Executive Secretary
American Society for Quality Control
Room 5036
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Make checks payable to:

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Editorial correspondence and requests for copyright releases should be addressed to

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Correspondence concerning news items and other matters appropriate for IQC NEWS SUPPLEMENT should be addressed to

E. H. Robinson
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4949 West 65th Street
Chicago 38, Ill.

Cost of Back Issues

Back issues, comprising Volumes I through VII are available at $8.00 per volume, including the Index. Individual issues at $1.50 each.

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PROGRAM NOTES

Sixth Annual Convention
American Society for Quality Control

Onondaga County War Memorial Auditorium, Syracuse, New York

Thursday, Friday, Saturday—May 22, 23, 24, 1952

IN ORDER to provide as concise a picture as possible of the Sixth Annual ASQC Convention, the program schedule as set up to date is presented briefly below. Following the program outline there is included as much additional information as is available at this writing.

POINTS OF INTEREST

Headquarters—War Memorial Auditorium
Exhibit Area—Lower Floor, War Memorial Auditorium
Technical Sessions—War Memorial Auditorium
Three Luncheons and Banquet—Lower Floor, War Memorial Auditorium
Information Desks—War Memorial Auditorium and Hotels Syracuse and Onondaga

EVENTS OF INTEREST

THURSDAY

Registration—8:30 to 10:30 AM—West Entrance, War Memorial Auditorium
Exhibits—9:00 AM to 6:00 PM
Opening Assembly—11:00 to 12:00 AM—Main Auditorium
DR. W. R. G. BAKER—Vice-President and General Manager, Electronics Division, General Electric Company
Luncheon—12:15 PM—Announcements
Ladies Program—A tour of local manufacturing establishments
Educational Sessions—2:00 to 5:00 PM
Technical Sessions—2:00 to 4:00 PM
Annual Meeting of ASQC—4:05 PM—Auditorium, 3rd Floor North
Annual Banquet—6:15 PM—ASQC Program
Committee Meetings—9:30 to 11:30 PM—Hotels

Editorial Board	Onondaga Hotel
Auditing Committee	Syracuse Hotel
Publicity Committee	Onondaga Hotel
Textile Committee	Onondaga Hotel
Technical Committee Chairmen	Syracuse Hotel

FRIDAY

Committee Meetings—8:00 to 10:00 AM—Hotels and Auditorium

Shewhart Medal Committee	Syracuse Hotel
Automotive Committee	Onondaga Hotel
Chemical Committee	Auditorium
General Committee Chairmen	Syracuse Hotel

Exhibits—9:00 AM to 6:00 PM
Educational Sessions—9:00 to 12:00 AM, 3:00 to 5:00 PM
Technical Sessions—10:00 to 12:00 AM, 3:00 to 5:00 PM
Luncheon—12:15 PM
Ladies Program—Luncheon in one of the area's noted restaurants
Electronics Trade Meeting—5:00 to 7:00 PM—Auditorium—All those connected with the Electronics Field
Committee Meetings—5:00 to 7:00 PM—Auditorium
Examining Committee
Convention Committee
Aircraft Committee
Standards Committee
Education Committee
Social Evening—9:00 to 12:00 PM—Hotel Syracuse

SATURDAY

Committee Meetings—8:00 AM to 9:30 AM—Hotels

Section Representatives	Syracuse Hotel
Membership Committee	Onondaga Hotel
Program Committee	Onondaga Hotel
Technical Societies	Onondaga Hotel
Brumbaugh Award Committee	Syracuse Hotel

Exhibits—9:00 AM to 5:00 PM
Educational Sessions—9:00 to 12:00 AM
Technical Sessions—9:30 to 11:30 AM
Luncheon—Noon—Mr. Hugo Weissbrodt, Works Manager, Fort Wayne Works, International Harvester Company, "*Quality Control, The Key to Improved Employee Relations*"
Board of Directors Meeting—2:00 PM—Onondaga Hotel
Convention Closing—5:00 PM

EDUCATIONAL PROGRAM

The marked success of the training program in Cleveland was so great that a similar course will be repeated on this year's program. The instructors will again be Messrs. Arthur Bender and George McDermott, Delco-Remy Division of General Motors Corporation, who handled last year's course. In addition, the instruction staff will include the services of Mr. Edward Oakley of the General Motors Institute.

The course will offer eleven hours of instruction in the basic tools of SQC, covering such topics as concepts of variation, average and range charts, fraction defec-

tive, and number of defects charts. Acceptance sampling will not be covered in this course. The material will be presented in such a manner that trainees need not possess a formal statistical background in order to profit from the instruction.

TECHNICAL SESSIONS

The names of the speakers who will offer us of the fruit of their labors, and the titles of the papers they will present, are listed below. As may be seen, these include some of the foremost names and topics in the statistical quality control field.

THURSDAY

CARL A. BENNETT, Chief Statistician, General Electric Company, Richland, Washington. "*Statistical Approach to Chemical Processing Problems*"

THOMAS A. BUDNE, Control Statistician, Quality Control Division, E. R. Squibb & Sons. "*The Error in Measurement*"

MR. FAY CARLSON, Supervisor of Statistical Methods, Sundstrand Machine Tool Company. "*A Survey of the Application of Mil-Std-105A in the Aircraft and Associated Industries*"

FRANK E. GRUBBS, Chief, Surveillance Branch, Ballistic Research Laboratory, Aberdeen Proving Ground. "*Some Examples of Statistical Methods in Army Ordnance*"

D. S. HAMBY, Assistant Professor, School of Textiles, North Carolina State College. "*Quality Control in Staple Fiber Manufacturing Processes*"

ORRIN W. HITCHCOCK, Quality Manager, Scintilla Magneto Division, Bendix Aviation Corporation. "*Quality Control in Precision Manufacture*"

ARCHIE R. JACKSON, Director of Quality Control, Allen B. Wrisley Company. "*A Complete Story of the Operation of a Receiving Department*"

DR. JOSEPH M. JURAN, Consulting Management Engineer. Dr. Juran and his panel of experts will conduct a forum on the following questions:

A. WHAT IS THE ROLE OF THE QUALITY CONTROL DEPARTMENT WITH RESPECT TO
   1. *The Company's Quality Policy*
   2. *Specification of Quality*
   3. *Vendor Relations*
   4. *Customer Relations*
   5. *Plant Processes*
   6. *Inspection*
   7. *Defect Prevention*
   8. *Statistics*

B. WHAT ARE THE ATTRIBUTES AND QUALIFICATIONS OF
   1. *The Chief of the Quality Control Department*
   2. *The Quality Control Engineer*

Panel Members

1. ERNEST H. ROBINSON, Director of Quality Control, Johnson & Johnson
2. RAYMOND S. SADDORIS, Director of Quality, A. O. Smith Corporation
3. HUGH M. SMALLWOOD, Research Chemist, U. S. Rubber Company, General Laboratory.

BERNARD H. LLOYD, Engineering Specialist in Statistics, Canadian Industries Limited. "*Statistical Approach to Bulk Sampling Problems*"

H. EARLE MOORE, Chief Inspector, McDonnell Aircraft Corporation. "*Quality Control Programs in the Aircraft Industry*"

AUGUST B. MUNDEL, Chief Engineer, Quality Control and Inspection Division, Sonotone Corporation. (Co-speaker with Ellis Ott.)

ELLIS R. OTT, Department of Mathematics, Rutgers University. "*Narrow-Limit Gages*"

JOHN H. REYNOLDS, Technical Control Statistician, Celanese Corporation of America. "*Controlling the Control Laboratories in a Chemical Fiber Manufacturing Plant*"

FRIDAY MORNING

CHARLES A. BICKING, Ordnance Engineer, Research and Development Division, Office of the Chief of Ordnance (Army), Department of Defense. "*Some Uses of Statistics in the Planning of Experiments*"

HOWARD BOLTON, Assistant Superintendent of Inspection, Harrison Radiator Division, General Motors Corporation. "*The Use of a Control Chart to Reduce Material Consumption*"

RICHARD H. EDE, Process Metallurgist, United States Steel Company. "*Quality Control of Steel Manufacture*"

ALLEN A. EVANS, Quality Control Engineer, International Harvester Company. "*Quality Control and Foundry Practice*"

ENOCH B. FERRELL, Switching Research Engineer, Bell Telephone Laboratories. "*Control Charts Using Mid-Ranges and Medians*"

EDWIN C. HARRINGTON, JR., Manager of Industrial Statistics, Monsanto Chemical Company. "*Increasing the Efficiency and Economy of Experimentation*"

PROF. JOHN HENRY, Department of Mechanical Engineering, University of Illinois. "*A Survey and Evaluation of Types of Quality Control Education*"

M. E. KING, Engineer, Quality Control Division, Bureau of Ordnance, Navy Department. "*Vendor Certification by Established Standards*"

CAPTAIN B. L. LUBELSKY, U.S.N., Assistant Director Quality Control Division, Bureau of Naval Ordnance. "*The Navy's Position*" (*MIL-STD-105A*)

AUGUST B. MUNDEL, Chief Engineer, Quality Control Division, Sonotone Corporation. Panel Member on "*Vendor Certification*"

PROF. EDWIN G. OLDS, Department of Mathematics, Carnegie Institute of Technology. "*The Need for Statistical Quality Control in Engineering Education*"

WILLIAM R. PABST, JR., Department of the Navy. "*Introducing the Principles of MIL-STD-105A*"

HARRY G. ROMIG, Quality Manager, Hughes Aircraft Company, Division Hughes Tool Company. "*Quality Control Techniques for Electronic Components*"

LEONARD A. SEDER, Chief Quality Control Engineer, Gillette Safety Razor Company. "*The Technique of Preventing Defectives*"

JOHN W. W. SULLIVAN, Metallurgist, American Iron and Steel Institute. "*Applicability and Inapplicability of MIL-STD-105A*"

CLIFFORD A. WALLACE, Director of Quality Control, Eastman Kodak, Camera Works. "*The Gage Laboratory—Its Equipment and Function to Accomplish Precision—An Ever-Ascending Spiral Toward Perfection*"

FRIDAY AFTERNOON

BRIG. GEN. WALTER G. BAIN, USAF, Chief, Quality Control Division, Air Materiel Command. "*Principles of Q5923*"

NEW! The Flexible Norton REINFORCED RESINOID Hub Wheel

Adds new speed, ease and safety to your portable grinding jobs

This new Norton BFR flexible *Reinforced* Hub Wheel is sure to step up the efficiency of your portable grinding and sanding equipment because:

It's a fast-cutting wheel . . . thanks to its sharp, durable ALUNDUM* abrasive and special resinoid bond.

It's a time-saving wheel for blending in contours and corners because it has the necessary flexibility.

It's a safe, strong wheel because it has *extra* fabric reinforcement molded into it. It holds together even if it should be accidentally cracked.

It can't be beat for cutting off small gates and risers and notching big ones, smoothing welds and contours, removing mold marks and rust prior to painting.

Team up this new Norton BFR flexible *Reinforced* Hub Wheel with the heavy-duty Norton BD semi-rigid Hub Wheel and you'll multiply the number of jobs you can profitably do with your portable grinders and sanders.

Ask your nearby Norton distributor about Norton BD and BFR *Reinforced* Hub Wheels. He's listed under "Grinding Wheels" in your classified telephone directory. Or write direct to Norton Company, Worcester 6, Mass.

QUALITY CONTROL—This new Reinforced Resinoid Hub Wheel, like all Norton grinding wheels, is made by processes which are quality controlled to assure quality products.

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ABRASIVES

*Trade Mark Reg. U. S. Pat. Off. and Foreign Countries

IRVING W. BURR, Professor of Mathematics, Purdue University. *"Fundamental Principles of Sequential Analysis"*

PAUL C. CLIFFORD, Professor of Mathematics, Montclair State Teachers College. *"Using Training Conferences as a Quality Control Catalyst"*

DANIEL B. DELURY, Director, Department of Mathematical Statistics, Ontario Research Foundation. *"Designing Experiments to Isolate Sources of Variation"*

ROBERT B. GRIFFITH, Quality Control Manager, Bossert Company, Division of Timken-Detroit Axle Company. *"Quality Control Means Less Salvage and Scrap"*

STEPHEN HARRISON, Biometrician, Research Laboratories, Kraft Foods Company. *"The Use of Statistics in Food Processing"*

HOWARD L. JONES, General Superintendent of Statistics, Illinois Bell Telephone Company. *"Some Problems in Sampling Accounting Records"*

NELSON G. MEAGLEY, Manager, Statistical Quality Control, Willys-Overland Motors. *"Engineering the Inspection of Manufacturing Processes"*

WALTER S. OLIVER, Quality Manager, Detroit Gear, Division Borg-Warner Corporation. *"Statistical Quality Control in Relation to Engineering"*

DAVID R. PERYAM, Chief, Acceptance Division, Food Laboratories, Quartermaster Food and Container Institute. *"Perception, Preference, Judgment—Cues to Food Quality"*

A. C. ROSANDER, Statistical Division, Bureau of Internal Revenue, U. S. Treasury Department. *"Probability Statistics Applied to Control of Tax-Return Operations"*

J. H. SIDEBOTTOM, Chairman, Aircraft Industries Association. *"Industry's Side of Mil-Std-Q5923"*

H. E. THOMPSON, Manager of Quality Control, Anaconda Wire and Cable Company. *"Achieving Quality-Mindedness Through Employee Communications"*

SATURDAY MORNING

J. N. BERRETONI, J. N. Berretoni and Associates. *"Controlling Quality During Manufacture of Small Lots"*

WILLIAM CUNNINGHAM, Quality Control Engineer, and JOHN T. MACDOUGALL, Chief Inspector, Saco-Lowell Shops. *"Applications of Statistical Quality Control in a Machine Shop Manufacturing Textile Machinery"*

ROBERT CURRIE, Assistant Manager, Analysis Department, Quality Control, Manufacturing Staff, Ford Motor Company. *"The Ford Program for Vendor Certification of Quality Level"*

GEORGE L. DIGGLES, Electrical Testing Laboratories. *"Early Development of the Statistical Method of Sampling in Industry"*

WYATT H. LEWIS, Quality Control Engineer, General Electric Company. *"Special Applications for Control Charts"*

PAUL J. MUNDIE, Partner, Humber and Mundie. *"The Human Factor in Quality Control"*

CARL E. NOBLE, Superintendent of Customer Acceptance Laboratories, Kimberly-Clark Corporation. *"Statistical Cost Control in the Paper Industry"*

WARREN R. PURCELL, Quality Control Manager, Brown Company. *"The Quality Control Engineer in the Pulp and Paper Industry"*

TRUMAN W. READ, Assistant to Chief Inspector, Technical, Hamilton Standard, Division, United Aircraft Corporation. *"The Continuous Lot Plot Plan"*

EDWARD A. REYNOLDS, Quality Manager, Conmar Products Corporation. *"Methods of Company Training for Quality Engineers and Supervisors"*

DORIAN SHAININ, Chief Inspector, Hamilton Standard, Division, United Aircraft Corporation. *"Vosp—A New Invention for Averaging Out Human Opinion in Visual Inspection"*

J. FREDERICK VERIGAN, Quality Control Engineer, Atlas Powder Company. *"The Operator is Interested"*

J. PHILIP WORTH, Chief Inspector, Electrolux Corporation. *"Consumer-Vendor Relations"*

Although you will find material of interest every day, some of you may not be able to attend the sessions on all three days. Therefore, there is appended below a list of times when subjects of interest to a particular group will be discussed. If you cannot find a pertinent cross-reference in the list of speakers and papers given above, it means that the information is not available at the moment. However, the subject will be covered at the time indicated, and a complete listing is given in the convention brochure.

Aircraft and Aircraft Industries—Thurs., Fri., PM
Armed Forces and Procurement—Thurs., Fri., AM—PM
Automotive—Friday PM, Saturday
Chemical—Thursday, Friday AM
Die Stamping—Friday PM
Education—Friday AM and PM
Electronics—Friday AM, Saturday
Food—Friday PM
Gauging and Gauge Laboratory—Friday AM
General Interest—Thurs., Friday AM—PM, Sat.
Management—Thursday
Mathematical Statistics—Friday PM
Office and Accounting—Friday PM
Precision Manufacture—Thursday, Friday PM
Pulp and Paper—Saturday
Receiving and In-Process Inspection—Thursday, Sat.
Steel Foundry and Fabricating—Friday AM
Textiles and Textile Machinery—Thursday, Saturday
Vendor Certification—Friday AM, Saturday

In addition to the interesting features of the Technical and Educational Programs outlined above, other services provided by the convention committee will undoubtedly appeal to you. Some of these are discussed briefly below.

EXHIBITS—Our exhibitors include several of the country's foremost manufacturers describing their quality control experiences, as well as many of the most outstanding gauge companies displaying the latest and best in gauging equipment.

BOOK BOOTH—Many of the new treatises in the Quality Control field, in a total of sixty different titles including most of the older standard texts and handbooks, will be available to you at our book booth (#58, 59, 60), east of the main exhibit area. At least nine of your favorite authors will be present at different periods during the convention to autograph your purchases or to discuss their favorite subjects with you.

LADIES PROGRAM—Ladies are, of course, invited to come to the convention to take part in the regular sessions. However, if they prefer, they are hereby bid

What kind of men?

What kind of men are the 2500 scientists and engineers of Bell Telephone Laboratories?

They are men of many types, yet they work well together, for all have good minds as a foundation, years of study in the fundamentals of their science and in the methods of research and design. Vital, too, is their teamwork — for without the co-operation of many individuals the products of research and development could never be perfected.

Above all else these men have "the spirit to adventure, the wit to question, and the wisdom to accept and use."

Such men can develop the world's finest telephone systems — and have done so.

Perhaps there is a place among them for you. Write the Employment Director, Bell Telephone Laboratories, New York 14.

BELL TELEPHONE LABORATORIES

• EXPLORING AND INVENTING, DEVISING AND PERFECTING FOR CONTINUED IMPROVEMENTS AND ECONOMIES IN TELEPHONE SERVICE

welcome to the special program set up for their entertainment. This consists of guided tours, on Thursday, through some Syracuse factories which manufacture items of great interest to the distaff side. On Friday, a special luncheon at a famous local establishment is in the cards. Transportation will be provided for all scheduled trips. A small fee will be necessary to cover the cost of this program.

TRANSACTIONS—An attractively bound volume of the technical papers, with full illustrations, awaits you at the transactions booth (#2), west of the main exhibit area.

SOCIAL EVENING—Everyone is invited to join in the fun when formality is put aside on Friday evening. Entertainment and refreshments until midnight will be furnished you for a pittance.

ASQC BOOTH—Officers and representatives of the Society will welcome your questions and membership applications at booths I, R, north of the main exhibit area.

CONVENTION BROCHURE—If you have not already received a copy of the brochure, listing all details and including a registration blank, or if you desire extra copies, please address your inquiry to the secretary of your section or to the convention Publicity Chairman,

Mr. Frank Caplan, Jr.
115 Maple Drive
Camillus, N. Y.

Make use of the registration blank as soon as you receive it, both for the convention and for a hotel reservation. First come, first served. Your registration fee will be gladly refunded if you notify us in advance that you will not be able to attend.

Preview of Convention Exhibits

BAUSCH & LOMB OPTICAL COMPANY

Booths 13-14

The Bausch & Lomb Ortho-Rater is a precision optical instrument scientifically designed for reliable and valid measurement of visual skills. As the basis of the Bausch & Lomb Industrial Vision Service, it has been successfully incorporated into the personnel testing programs of hundreds of industrial concerns. Among the many benefits resulting from this Service have been increases in quality and quantity of production from 15 to 20 percent. Reductions in work rejects of up to 50 percent have been recorded.

Bausch & Lomb Optical Co., of Rochester, N. Y. will demonstrate a complete group of control and inspection instruments including a Contour Measuring Projector, Tool Maker's Microscope, Stereomicroscope, Shop Microscope, Brinell Microscope, Wide Field Tube. In addition, the recently announced Balcrometer, a highly precise 3" thickness measuring gauge will be shown by E. E. Koch from the Industrial Sales Department of the Company's Rochester offices. Supplementing these instruments B&L will show a full line of readers and magnifiers for industrial use.

BROWN & SHARPE MANUFACTURING COMPANY

Booth No. 50

On display in the Brown & Sharpe booth will be a complete line of Electronic Production Gaging and Inspection Equipment providing reliable measurements electronically in units varying from .0001" to .00001". A new Electronic Caliper Gage recently introduced will be on exhibit as well.

Representative Johansson Gage Blocks and Accessories, and displays featuring Jo-Blocks, a complete line of Brown & Sharpe Precision Tools including the new Brown & Sharpe Line of Micrometers, Permanent Magnet Chucks and other items from the line of Brown & Sharpe Precision Products used extensively in aiding in the maintenance of Quality Control, also, will be on exhibit.

COLLINS MICRO-FLAT COMPANY

Booth No. 7

Collins Micro-Flat Company, Los Angeles, California, exhibiting "Micro-Flat" black granite surface plates and stands. Method of checking surface accuracy with auto-collimation (optical checking) will be displayed.

Range of sizes produced is 9" x 12" thru 48" x 120" with accuracies to 50 millionths. Lee Collins, president, will be on hand at show.

COSA CORPORATION

Booth No. 49

The equipment manufactured by the SIGMA INSTRUMENT CO. includes Multi-Dimension Inspection Machines of the fully and semi-automatic type. The standard machine exhibited is tooled up to inspect nozzles. Standard fixtures are shown to demonstrate the adaptability of this machine to inspect other parts.

The SIGMA Mechanical Turret Comparator is a new instrument designed for quality control work. It incorporates a comparator head, accurate to four millionths of an inch, below which a 10-station turret is mounted. The turret is fitted with ten SIGMA fixtures which enable up to ten dimensions to be measured separately.

The SIGMA Electrical Gauge-room Comparator and SIGMA Electric Signal Gauges are on view.

The ISOMA Instruments exhibited include the Hardness Tester which has been developed for the determination of Vickers hardness to a high degree of accuracy. ISOMA Tool Makers Microscopes are suitable for the inspection of very small pieces and incorporate diascopical and episcopical lighting.

ELLIOTT SERVICE COMPANY

Booth No. 16

Elliott "Quality-Cost" Displays for departmental posting in large and small manufacturing plants to help stimulate employee quality-consciousness.

Complete bulletin board service to help strengthen management's daily point of contact with employees by skilful and colorful poster-presentation of such subjects requiring plant-wide cooperation as quality workmanship, waste elimination and accident prevention. Bulletin boards are furnished in silver-gray, hammered-tone or green baked enamel finish. Chrome finished 3-panel display fixture also available for departmental publicity. Special Service for Textiles.

"MANAGEMENT INFORMATION for Foremen and Supervisors" a weekly bulletin covering quality maintenance, waste and cost reduction, training, human relations, safety. Supervisory training outlines and booklets on similar subjects.

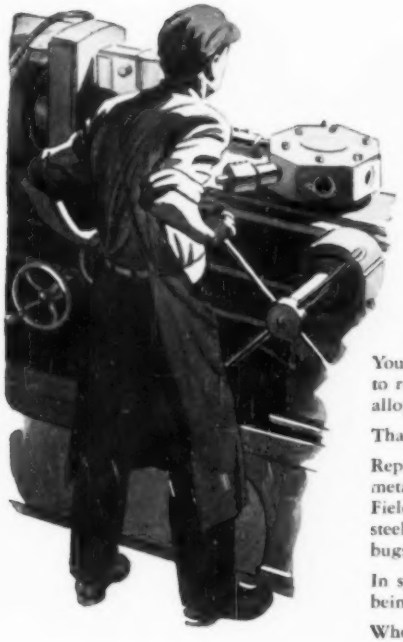
Suggestion System Service including THINK-Stimulator Displays, bulletins and suggestion panel boxes.

ENGINEERS SPECIALTIES DIVISION

Booths 5-6

Gaging by Optical Projection will be demonstrated in Booths 5 and 6 at the sixth annual Quality Control Exhibit in Syracuse, New York, May 22, 23 and 24, 1952.

a few words about alloy steels



and how we can help you switch to ALTERNATE ALLOY GRADES

You've probably had trouble getting the alloy steels you've been accustomed to running. You've got the headache of choosing the best available alternate alloys, plus the headaches of how to machine and heat-treat them.

That's where we can help . . .

Republic 3-Dimension Metallurgical Service combines the experience of your metallurgist and your production men with our 3-man team . . . the Republic Field and Laboratory and Mill Metallurgists. You tell us what you want the steel to do . . . we tell you the best available alternate, help you take the bugs out of using it.

In spite of restrictions you can probably switch to one of the many grades being made by Republic . . . world's largest producer of alloy and stainless steels.

When may our Republic Field Metallurgist call?

REPUBLIC STEEL CORPORATION
Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, N.Y.

LAB MILL FIELD
3-DIMENSION Metallurgical Service

Republic ALLOY STEELS
REPUBLIC STEEL

Other Republic Products include Carbon and Stainless Steels—Sheets, Strip, Plates, Pipe, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing

This demonstration will include actual examples of how projection inspection methods reduce costs of gaging operations.

New applications of Optical Projection for quality control and inspection operations have recently been developed and will be shown to the public for the first time.

FEDERAL PRODUCTS CORPORATION

Booth No. 23

To quote from a letter from Mr. I. A. Hunt of the Sales Promotion and Advertising Department:

"We will display the work we have done in promoting the use of Quality Control by statistical methods, what we have done in conducting educational classes. The subject: publicity, charts, stationery available for conducting Quality Control in your plant, some case histories and the gages which are used in applying Quality Control by statistical methods.

"Our Quality Control Engineer, Mr. Clifford Kennedy, will also be present to answer questions in regard to practical application of the subject."

FORD MOTOR COMPANY

Booths 36-37

The Ford Motor Company will exhibit examples of Chart Control Techniques as applied to the various phases of Automotive Manufacturing.

Keynoted will be the Quality Level Certification Program, illustrating the various steps from initial discussions between supplier and consumer to final certification. This display will include forms used in Receiving Inspection and some of the various types of control charts used by the company and suppliers now certified.

Other features will include a Training Program display and a series of Chart Control Pamphlets, which will be available at the exhibit for distribution.

FRIDEN CALCULATING MACHINE COMPANY, INC.

Booth No. 4

The Friden Fully Automatic Calculator, which will be exhibited, is ideally suited to quality control calculations. Automatic accumulation of products and Magic Division, exclusive Friden features, facilitate the rapid calculation of averages. The Friden exclusive separate multiplying keyboard and control keys provide instantaneous, automatic multiplication, including automatic dial clearance, carriage positioning and decimal point. Separate control keys eliminate the need for conditioning the machine for accumulative or negative multiplication. Constant factors can be locked on either keyboard, and both are visible before calculation.

Magic Division is completely automatic division, including automatic positioning of the carriage and automatic decimal point. Individual answers may be automatically accumulated for a grand total.

A positive keyboard lock and individual column locks retain a factor set on the keyboard and prevent accidental depression or release of any key. Split Dial Clearance and Accumulator locks permit two amounts to be registered in the upper dials simultaneously and accumulated or cleared separately.

The exhibit will be supervised by Mr. W. M. Ryder, Manager, Syracuse Agency, 114 S. Warren Street, Syracuse, N. Y.

GRAHAM-MINTEL

Booth No. 31

You will find the exhibit and demonstration of Graham-Mintel electronic measuring instruments in Booth 31 at the corner of the center aisle.

There will be demonstrations of our MICRO-AC electronic micro-comparator used for checking dimensions directly in millionths of an inch. It is used for checking gage blocks, master gages and the like where extreme sensitivity and precision are required.

We will also have our INDI-AC electronic indicator for general purpose gaging with laboratory precision; particularly for checking set-ups, runout and for surface plate work.

You will also see the PAR-AC electronic production gage for fast shop gaging with dependable high precision. A single PAR-AC provides for repetitive comparator measurements. With multiple gage heads, several dimensions may be checked in succession using a single-meter amplifier, or checked successively in pairs using an amplifier with two meters.

A permanent record of all these measurements may be kept by the use of a pen recorder attached to the amplifier to give an inked tape record.

JOHNSON GAGE COMPANY

Booths 24-25

The Johnson Gage Company exhibit is based on the Johnson System of Screw-thread Gaging and Quality Control. It includes "fixed" type RING and SNAP Gages for conventional inspection and "attribute" type quality control, and "indicating" type Comparators for conventional inspection and "variable" type quality control. The RING-Snap and ROLL-Snap Comparators illustrated embody the fundamental principles of Johnson Gage design for determining Screw-thread Accuracy and Assembleability. Various special Comparator applications are also included that involve squareness and concentricity checks. The Johnson "Setting and Wear-check" Plug Gages—means for determining degree and type of wear in Thread Gages and Comparators—are also exhibited.

JONES & LAMSON MACHINE COMPANY

Booth No. 30

Two of the more universally used Optical Comparators will be in operation at the Jones & Lamson Syracuse display in May—the BC-14 and the PC-14. Both comparison and measurement operations will be demonstrated. One of them will be on an Ordnance job, for which the BC-14AA J&L Comparator, or equivalent, has been specified as standard. Large photos and descriptions of the other nine J&L models will be available, as well as a full color sound movie on the Comparator. This is a brand new film, and tells the complete optical Quality Control story, including current work being done on both gas and steam turbine blade checking.

MAGNAFLUX CORPORATION

Booth No. 1

Non-Destructive Testing in Process Control

Production Control and process control depend basically upon economical and reliable data on production variations *as they occur*. Location of crack-type defects and control of causes as these defects occur is the industrial practice demonstrated by Magnaflux Corporation. A wide variety of Non-Destructive Testing methods and equipment are available for all metals and nearly all non-metals, developed and made available by Magnaflux Corporation.

Magnaflux and Magnaglo for magnetic metal products; Zyglo for non-magnetic metals; Partek and Statiflux for "green" and fired ceramics, for concrete, for powdered metals, etc.; these and other methods by Magnaflux are more widely used in industry than any other Non-Destructive Test methods. All are engineered and in operation for in-line volume or sampling production inspection operations at minimum cost per piece.

Statistical sampling data and Quality Control charts as obtained in production situations will be shown by Magnaflux, together with typical defects as located. Engineering information is supplied on the most efficient inspection practices for any defect-locating problem.

A NEW HANDBOOK FOR QUALITY CONTROL MEN

A Complete Text on the Use of Gage Blocks, Light Wave Measurement Equipment and Statistical Sampling for Dimensional Control

HERE is a new 256-page book that contains complete information on the theory and use of Gage Blocks and Accessories, Monolites, Optical Flats, Electric Comparator Gages and related equipment for precision dimensional measurement. It explains fully the "reading" of millionths-of-an-inch with light wave interference bands; shows why such accuracy is necessary to control thousandths-inch production tolerances. Also covered are recommended procedures for statistical sampling of parts for dimensional control and a discussion of *mobile inspection systems* for checking working gages and parts right at the machines in the shop.

This book is a most valuable reference for the library of any man concerned with use of dimensional gaging and control. A copy is available without cost to any ASQC member who requests it on his company letterhead. Also available in quantity for training and educational purposes at $3.50 per copy. Call your local DoALL Sales-Service Store or send the coupon to:

THE DoALL COMPANY • 254 N. Laurel Ave., Des Plaines, Illinois

QB-8

DoALL BLOCKS—fifteen standard English and metric sets from 6-pieces to 118-pieces.

NEW DoALL MONOLITE—an improved high-intensity Helium light source with many new features.

DoALL OPTICAL FLATS—high quality fused quartz; square and round types up to 14" diameter.

DoALL ASK FOR BULLETINS

FREE
TO ASQC MEMBERS

FILL IN AND MAIL COUPON

THE DoALL COMPANY
Des Plaines, Illinois

I would like a free copy of "The Science of Precision Measurement".

Name .....

Title .....

Company .....

Street Address .....

City ..... Zone No. ..... State .....

MARCHANT CALCULATING MACHINE COMPANY

Booths 38-39

Will exhibit two top models in its line of fully automatic and semi-automatic electric calculators: the FIGUREMASTER, with push-button multiplication, automatic division line-up and other features designed for heavy volume figurework; and the FIGUREMATIC, offering push-button multiplication at a lower price for offices where figurework is lighter or consists mostly of multiplication problems.

Representatives of the Company's Syracuse and New York offices will give demonstrations of the use of Marchant Calculators. Several additional Marchants will be available for visitors to operate in solving Quality Control or other mathematical problems.

Of particular interest to Quality Control engineers will be demonstrations of such figurework as standard deviation and interpolation—for which the Marchant is ideally suited.

James J. O'Sullivan, Marchant's Syracuse Agency Manager, will be in charge of the booth.

MONROE CALCULATING MACHINE

Booths 10-11

The Monroe booklet entitled "Quality Control" will be available in booths 10 and 11 for distribution to all Quality Control engineers and statisticians who have not, as yet, received copies.

The feature attraction of the Monroe exhibit this year will be the Square-Matic Monroe, the calculator with the automatic squaring lock, together with the Monroe two-register adding machine, which form the ideal statistical computation unit.

The remainder of the exhibit will be devoted to demonstrations throughout the exhibition hours of the simplified Monroe methods and control chart techniques involving the average and range methods; standard deviations; chi-square; linear, multiple and partial correlations; extraction of roots; and raising numbers to powers.

The exhibit will be under the direction of:

E. I. Small, General Offices, Orange, New Jersey
C. D. Furer, Manager, Syracuse, New York
E. L. Maurer, Jr., Representative, Syracuse, New York

NATIONAL TOOL COMPANY

Booth No. 15

National Tool Company's exhibit in Space No. 15 will feature the versatile Pocket Comparator, an optical measuring instrument for fast accurate checking.

Since its introduction two years ago, the Pocket Comparator has gained steadily in popularity as Quality Control divisions of the nation's foremost industries have become aware of the instrument's adaptability to more diversified checking operations.

The Pocket Comparator is manufactured by Bell and Howell Company, a firm whose name is synonymous with precision and fine optics.

SHEFFIELD CORPORATION

Booths 56-57

Included in the exhibit of the Sheffield Corporation, Dayton, Ohio, will be several Precisionaire process control applications, indicating types of standard gages and comparators, also precision measuring instruments for use in the gage laboratory and tool room to control the gages and instruments actually used in process control.

Of especial interest to quality control experts will be the Precisionaire 18-column gage with an "Airechart" to check the contour of blades used in jet engines. The airfoil of the blade is checked at 18 points simultaneously and the patterns of the float positions of the "Airechart" indicate not only the contour of the blade but its position on its base.

Toolroom instruments will include a Precisionaire Gage Block Checker having an amplification of 100,000 to 1, graduated scale being in one-millionths of an inch, each millionth being represented by approximately $\frac{1}{8}$" on the scale. A Precisionaire Internalchek for measuring small diameters down to .120", Electronic Height Gage, Electronic Leadchek, Electronic Internal and External Measuring Instruments and high amplification Visual Gages are other toolroom gages to be shown.

Qualified gage application engineers thoroughly versed in quality control will be on hand to counsel with those attending the Exposition.

L. S. STARRETT COMPANY

Booth No. 28

The L. S. Starrett Company of Athol, Massachusetts, manufactures a complete line of Dial Indicators and Dial Gages for Production Inspection and Quality Control and will display them at the 6th Annual Convention of ASQC.

Also on display will be many other items essential to the Quality Control Program including Micrometers of all types with the new satin chrome finish, Height Gages, Gear Tooth Vernier Calipers, Depth Gages, and many other Precision Hand Measuring Tools.

In attendance at Starrett Booth No. 28 in the exhibit area of the Convention will be Mr. J. R. Lynch, Factory Representative in the Rochester and Syracuse Area; Mr. R. E. Abare, Factory Representative in the Cleveland Area; Mr. R. E. Brackett, Dial Gage Sales Engineer, and several Factory Engineers.

SYLVANIA ELECTRIC

Booths 45-46

Sylvania Electric Products Inc. is a leading producer of products for lighting and electronics. These products include fluorescent and incandescent lamps, radio and television tubes, radio and television sets, tungsten and chemical products, small metal parts and plastics. As a leader Sylvania must maintain the quality of the products which made it a leader.

Sylvania's exhibit illustrates the wide range of products in its line. It also illustrates how these products through vertical integration result in close quality control from basic materials to finished products. Through this vertical integration Sylvania is able to maintain consistent quality in all of its products.

The exhibit shows component parts of tubes, lamps, fixtures and other products, as well as the finished products. In the field of research quality control has contributed to vertical integration by finding new and better methods of controlling the quality of the finished product through careful control in the manufacture of parts.

Shown, too, is a representative group of Sylvania factories. In all, Sylvania operates over 30 factories in eight states. Through small, well integrated groups of employees, Sylvania is better able to offer better working conditions, better employee relations with an end result of better quality workmanship in the assembly of its products.

TAFT-PEIRCE MANUFACTURING COMPANY

Booth No. 22

The exhibit of the Taft-Peirce Manufacturing Company will be focused entirely on quality control equipment, including both time-tested and completely new products.

Plain and thread gages of the ring, plug and snap variety will be shown, including several of Tungsten Carbide and Norbide. Also the famous Taft-Peirce micrometer plug gage and a selection of special gages will be on display.

The feature of the exhibit will be the Air Gage display. In addition to a group of standard air snaps, air plugs and air rings, with and without hose extensions, an air-electric device will be operating

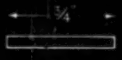
100% INSPECTION at Lowest unit cost

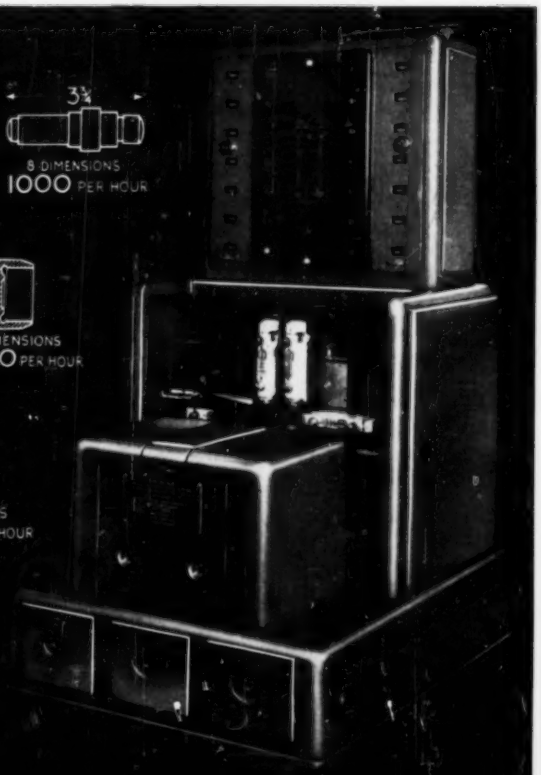
SIGMA HIGH SPEED

MULTI-DIMENSION INSPECTION MACHINES

Important Features

- Fully Automatic, Semi-Automatic or Hand Operated.
- Check up to 12 dimensions on each piece, simultaneously. *Sigma has built special machines to check as many as 28 dimensions simultaneously on a turbine blade in 12 seconds.*
- Checks External or Internal Dimensions, Depths, Profiles, Concentricity, Tapers, Squareness of Faces.
- Easily and quickly set to the required tolerances.
- Rapid change of set-up from one part to another.
- Handles pieces from ½" to 4" wide and up to 8" long.
- Results are instantly visible by signal lights.
- Guaranteed accuracy of Electric Signal Gauge is .00005".
- Inspects up to 10,000 pieces per hour.
- Counts, tabulates and ejects pieces into separate compartments for correct, oversize and undersize parts.





Sigma Automatic Multi-dimensional Inspection Machine with magazine feed for checking six dimensions on wheel studs. Output: 2,500 per hour.

Send us blue prints or samples of parts you want checked, giving us your inspection requirements. Our Engineers will be glad to make suitable recommendations.

SEE THESE MACHINES IN OPERATION AT COSA'S NEW YORK SHOW ROOM OR SEND FOR DESCRIPTIVE LITERATURE.

MANUFACTURED BY SIGMA INSTRUMENT CO., LTD., LETCHWORTH, ENGLAND

COSA CORPORATION

405 Lexington Ave., New York 17

Your source for all Precision Machine Tools — from Small Bench Lathes to Large Boring Mills

IN DETROIT AREA contact DETROIT-COSA CORPORATION, 16923 James Couzens Highway, Detroit 35, Mich.

continuously to illustrate the unique translation of no-contact air gaging to flashing light indication. A .058" air plug will show how air gaging can be applied successfully to the checking of very small diameters.

The Taft-Peirce "Roto-Chek", a novel power operated thread gaging unit, will be of interest to those anxious to accomplish more rapid inspection of threaded parts.

In addition, several gage engineers will be on hand to discuss specific gaging problems.

Recent Lot Plot Experiences Around the Country*

DORIAN SHAININ

Hamilton Standard Division, United Aircraft Corporation

ON NOVEMBER 19, 1947 the first public explanation of the details of operation of the Lot Plot plan was presented before a meeting of the Boston Society for Quality Control. Interest in the plan has been growing steadily. Hamilton Standard has been kind enough to permit anyone to copy the form and use the method. The file of copies of such Lot Plot forms sent from the field covers an interesting cross section of industry:

Air Conditioning
York Corp.
York, Pa.

Aircraft
Boeing Aircraft
Seattle, Wash.
Chance Vought Aircraft
Dallas, Texas
Republic Aviation
Farmingdale, N. Y.

Aircraft Accessories
Bendix Aviation Corp.
Hamilton Division
Hamilton, Ohio
Bendix Aviation
South Bend, Ind.
Pesco Products Div.
Bedford, Ohio
Scintilla Magneto Div.
Sidney, N. Y.

Aircraft Engines
Allison Division GMC
Indianapolis, Ind.
Pratt & Whitney
East Hartford, Conn.

Automotive
Willys-Overland Motors
Toledo, Ohio

Automotive Accessories
Delco-Remy Div., GMC
Anderson, Ind.
King Seeley Corp.
Ann Arbor, Mich.

Bearings
Fafnir Bearing Co.
New Britain, Conn.
New Departure Div., GMC
Bristol, Conn.
Torrington Company
Standard Plant
Torrington, Conn.

Brushes
Fuller Brush Co.
Hartford, Conn.

Business Machines
Hedman Co.
Chicago, Ill.
I.B.M. Corp.
Endicott, N. Y.
Pitney-Bowes
Stamford, Conn.
Underwood Corp.
Hartford, Conn.
Victor Adding Machine
Chicago, Ill.

Carpets
Bigelow-Sanford
Thompsonville, Conn.

Counters
Veedor Root Inc.
Hartford, Conn.

Electrical
The Bristol Company
Waterbury, Conn.
Collins Radio Co.
Cedar Rapids, Iowa
Crosley Division
AVCO Mfg. Corp.
Cincinnati, Ohio
Delco Radio Div., GMC
Kokomo, Ind.
Hart Mfg. Company
Hartford, Conn.
Silex Company
Hartford, Conn.
Wagner Electric Company
St. Louis, Mo.

Food Machines
Sanitary Scale Company
Belvidere, Ill.

Food Packaging
American Can Co.
New York City

Governors
Woodward Governor
Rockford, Ill.

Hardware
Allen Mfg. Company
Hartford, Conn.
Capwell Mfg. Company
Hartford, Conn.
Lamson & Sessions Co.
Cleveland, Ohio
Standard Pressed Steel
Jenkintown, Pa.

Industrial Chains
Whitney Chain & Mfg.
Hartford, Conn.

Machine Shop
ExCello Corporation
Detroit, Mich.
Inland Mfg. Company
Omaha, Nebr.
Perkins Machine & Gear
Springfield, Mass.

Ordnance
Frankford Arsenal
Philadelphia, Pa.
Nebraska Ordnance Plant
Fremont, Nebr.

Pens & Pencils
Esterbrook Pen Co.
Camden, N. J.

Plumbing
Crane Company
Chattanooga Div.
Chattanooga, Tenn.

Pottery
Shenango Pottery Co.
New Castle, Pa.

Pressed Metal Products
Eversharp Schick
Bridgeport, Conn.
Scovill Mfg. Co.
Waterbury, Conn.

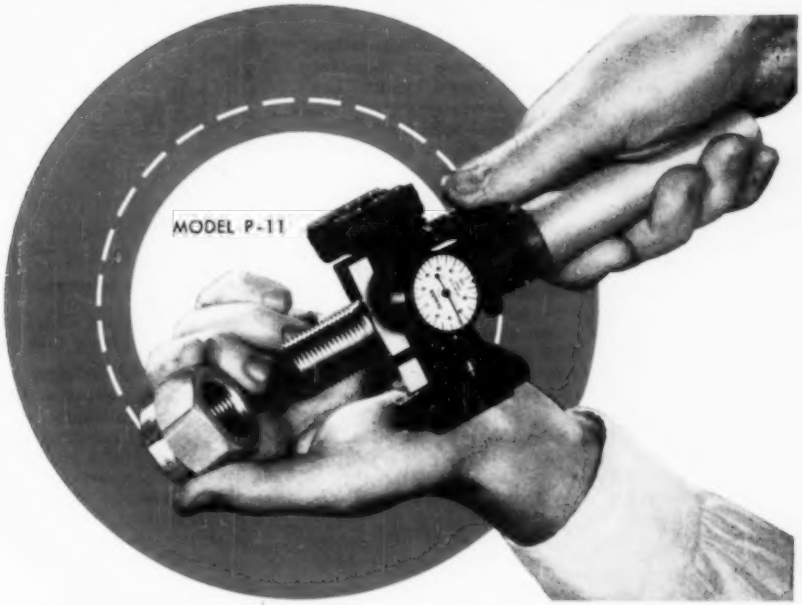
Public Utilities
Southern Cal. Gas Co.
Los Angeles, Cal.

Special Machinery
Torrington Mfg. Co.
Impellor Division
Torrington, Conn.

Springs
American Coil Spring
Muskegon, Mich.
Wm. D. Gibson Co.
Chicago, Ill.
International Spring Co.
Chicago, Ill.
Raymond Mfg. Co.
Corry, Pa.
Wallace Barnes
Bristol, Conn.

*Paper presented at the Fifth National Convention, ASQC, Cleveland, Ohio, May 23, 1951.

BRYANT INTERNAL THREAD GAGE



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STREET_____

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CRITICISMS AND COMMENTS

All has not been happy with the Lot Plot—it has been criticized. It is true that its use at Hamilton Standard has been most effective; several hundred Lot Plots are being made each week in receiving inspection and in the final checking of material fabricated in the plant; it is saving over a quarter of a million dollars each year in inspection wages compared to the previous practice of 100% inspection; and it has cut complaints from the assembly floor and from our customers from a few each month down to a single one in five years of operation. This one complaint was the first instance in the release of over 200,000,000 items by the plan. Any sampling plan guarantees there is a risk involved. The risk is extremely small for the Lot Plot plan but nevertheless it is there. The tremendous improvement in results over those of any 100% or multi-hundred percent inspection plan is of extreme value to us in the aircraft industry where risks must be kept almost to the vanishing point.

Criticisms of the Lot Plot have fallen into four categories:

1. The plan is too tight for most industries.
2. Its mathematical background is not sufficiently well established.
3. Several frequency histograms of fifty pieces each from the same lot will not show the same shape of distribution.
4. The staggered scale employed on the form is confusing.

1. It should be explained that the purpose of the Lot Plot is not to operate in the manner of conventional sampling plans. There, material of a given percent defective will be acceptable a certain percentage of the time and will be rejectable a percentage equal to 100 minus this first percentage *in the long run*. Also the Lot Plot does not involve screening of rejected lots in order to achieve an average outgoing quality limit. Its purpose is to get as accurate a picture of the condition of the particular lot in question as is humanly and practically possible. A measure of how close the data come to reflecting the condition of the lot, how small the sample error is kept can be seen from the "tight" operating characteristic curve (Figure 1). After you have this near-accurate picture of the lot for each characteristic being checked, then you can use judgment for the individual cases to decide the fate of the lot. It might be accepted as is, a certain minimum number of usable pieces might be found from the lot to be able to continue your assembly operations, or the lot might be returned to the manufacturing source. There its disposition could be scrap, use elsewhere, or a screening in the hope that the number of objectionable defective pieces may be reduced to the extent that the lot will pass another Lot Plot upon resubmission. It is doubtful that any plant can honestly say that by picking one or several levels of AQL's or AOQL's or lot tolerances for different classes of material, it is operating as economically as possible. The multitude of specifications, the changing degree at different times of urgency for the use of components, the continual shifting of critical values of certain specifications, as test and service experience is obtained, are all common experiences. These factors make it costly to say *in advance*, for this part or this group of specifications, we want to set a limit of so much percent defective that we will take in the long run; or that for a given defectiveness we will reject the lots only a certain fixed percentage of the time in the long run.

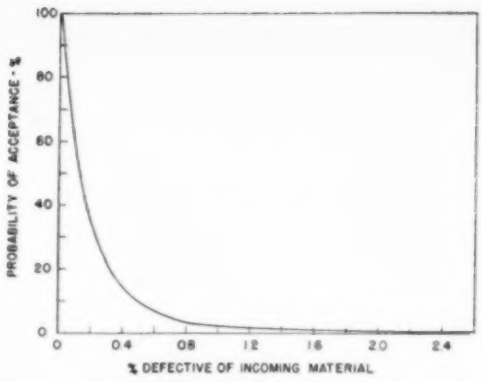

Figure 1—**Operating Characteristic Curve for Lot Plot Acceptance Plan, n = 50.**

2. Although they are unusual, the irregular distributions of certain samples make it quite a chore to establish confidence limits, unless you plan to gain nothing mathematically from the distribution itself. The methods for analyzing such things as skewed distributions and those with a kurtosis greater or less than plus three were designed to give an estimate of the lot limit position in each case that is either so close to the true position that it will not affect the disposition of the sampled lot, or else it will be in error in a conservative direction.[1] Thus it was possible to bring the method of analysis down to where anyone who can read a micrometer can be taught in less than a week to analyze Lot Plots completely.
3. The shape of the distribution of the sample of 50 items will not always reflect the shape of the distribution of the lot. The sampling error of the number of items found by chance in each of the cells of the distribution has only a minor effect on the final results. Close control is maintained over the sampling error involved in the estimation of the mean and of the standard deviation. Noticeable changes in the shape of the distributions of samples alter the method of analysis employed for each. The result from such samples from a single lot should, a very high percentage of the time, then be either so close to the lot conditions as to have no practical effect on final decisions, or so that any errors involved will be in a safe direction.
4. The staggered scale arrangement has been retained on the new Lot Plot form because it correctly shows the cell boundaries. These cell boundaries correspond to markings on the variable type gage. When properly instructed, an inspector will find that he can proceed more rapidly and more accurately to enter results on the form as falling between the certain cell boundaries that he sees on his indicating device as well as on his

1. "The Hamilton Standard Lot Plot Method of Acceptance Sampling by Variables." July 1950 issue of INDUSTRIAL QUALITY CONTROL.

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HAMILTON STANDARD
LOT PLOT AND QUALITY REVIEW ORDER

VENDOR XYZ Co, Rochester, N.Y. PART NAME Retainer PART NO. 55037
P.O. NO. 243524 R.S. NO. 29751A QUANTITY 1400 DATE INSP. 2-17-48
SPEC. .687 +.000 -.001 O.D. INSPECTOR #32 SAMPLE SIZE 50

VALUE	IND.	LINE NO.	0	5	10	15	20
		+10					
		+9	UPPER SPEC.				
.68700	+8	+8					
95	+7	+7				ULL	
90	+6	+6					
85	+5	+5	1				—
80	+4	+4	8 10				—
.68675	+3	+3	6 6 8				+3
70	+2	+2	1 3 5 5 6 7 9				+2
65	+1	+1	2 4 4 5 6 7 8 8 10				+2
60	0	0	2 3 4 5 5 7 9 9 10 10			X	—
55	-1	-1	1 2 2 4 6 7 9				—
.68650	-2	-2	1 1 3 3 4 9				—
45	-3	-3	3 10				—
40	-4	-4	2 7				—
35	-5	-5	8				—
30	-6	-6				LLL	+7
.68625	-7	-7					x 2
		-8					+14
		-9					÷100
		-10	LOWER SPEC. (68600)				+.14

PLEASE!
ASK YOUR OPERATOR TO STUDY THIS DIAGRAM AND:—

RANGE	
1	7
2	5
3	5
4	3
5	2
6	4
7	6
8	9
9	4
10	7
11	
12	
13	
14	
15	

☐ MOVE BASIC PRODUCTION SIZE (TOOL SETTING, DIE SIZE, MOLD CAVITY, ETC.) _____ IN _____ DIRECTION

☐ REDUCE PROCESS SPREAD AT LEAST _____

☐ MAKE THE TWO BASIC PRODUCTION SIZES CENTER AT _____

☐ EXPLAIN WHY RED CIRCLED PIECES WERE LEFT IN THE LOT

IF SOME OF THE ABOVE ARE CHECKED, LOOK FOR NEXT LOT PLOT TO SEE IF YOUR ADJUSTMENTS WERE SUCCESSFUL

☒ ACCEPT OUR CONGRATULATIONS FOR A GOOD JOB! THE OTHER SIDE OF THIS SHEET TELLS YOU HOW TO GET A CHECK MARK IN THIS LAST BOX ALL THE TIME

2R = 5.3
3σ = 6.76
ΣX = +7
X̄ = +.14

DISPOSITION	
ACCEPT (CO. INSP.)	E Vernon
Q.R. ACCEPT (HS QR)	
GOV'T. INSPECTOR	T.R

BEYOND	%	EXTENT
HIGH SPEC.	OK	
LOW SPEC.	OK	

ATTRIBUTE SAMPLE DATA
SAMPLE OF ___ SHOWS ___ PIECES ___

REMARKS—

Figure 2—**Revised Lot Plot Form, Face Side of Form**

Lot Plot form. The new form attempts to make this situation clear by showing that the listed values are those of the lines. Any piece must give a measurement that falls between a pair of lines on the gage. If the inspector is in doubt because his pointer is "right on the line" he can then enter his reading either above or below that line. It will make no practical difference to the final results.

IMPROVEMENTS IN THE LOT PLOT FORM

Other improvements to the form involve the addition of

(1) a blank column for actual indicator or gage division markings when applicable, to facilitate the entering of results;
(2) notations for vendor coordination;
(3) the reverse side of the form shows how to keep a process in statistical control with a control chart; an attempt to describe, explain and illustrate the use of sum and range charts.

(See Figures 2 and 3.) Sum and average columns are eliminated, the calculation of the average now being made by the method described below. This method cuts about eight minutes from the time to complete the inspection.

a. Cut out the column of plus and minus line values from a blank Lot Plot form.
b. Place this column to cover the line values on the Lot Plot so that the zero cell falls opposite the mode or longest horizontal row of entries.
c. Note whether the +1 or −1 cell contains the most readings.
d. Compare the quantities in these two cells by moving the cut column of paper horizontally to the right until the smaller of the two compared rows is just covered.
e. Count the remaining uncovered squares in the partially covered cell row, multiply this count by the cell sign and value, and enter the result at tne extreme right side of the grid in that cell row.
f. Repeat using the +2 and −2 cells, and continue until only the zero cell remains.
g. Total the results algebraically and enter the answer opposite "Totals" in the lower right hand section of the Plot.
h. Multiply this answer by 2 and point off 2 decimal places to the left.
i. Enter this result in the ($\bar{X}$ −) space.
j. Point off from the middle of the mode or peak cell

SIMPLE PROCESS CONTROL

USING A SUM AND RANGE CHART

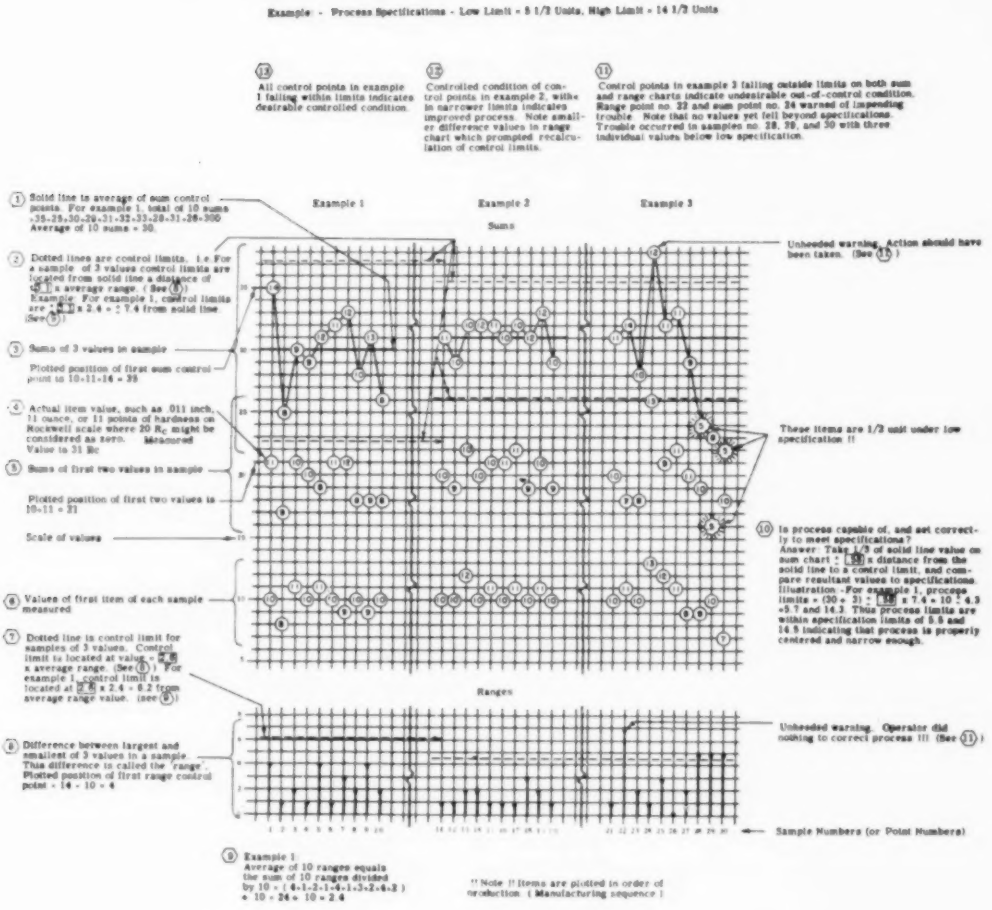
Example - Process Specifications - Low Limit = 9 1/2 Units, High Limit = 14 1/2 Units
13 All control points in example 1 falling within limits indicates desirable controlled condition.
12 Controlled condition of control points in example 2, within narrower limits indicates improved process. Note smaller difference values in range chart which prompted recalculation of control limits.
11 Control points in example 3 falling outside limits on both sum and range charts indicate undesirable out-of-control condition. Range point no. 22 and sum point no. 24 warned of impending trouble. Note that no values yet fell beyond specifications. Trouble occurred in samples no. 28, 29, and 30 with three individual values below low specification.
1 Solid line is average of sum control points. For example 1, total of 10 sums =28+29+30+29+31+32+33+29+31+26=300 Average of 10 sums = 30.
2 Dotted lines are control limits. I.e. For a sample of 3 values control limits are located from solid line a distance of 2.6 x average range. (See 6) Example. For example 1, control limits are 2.6 x 2.6 = ± 7.4 from solid line. (See 9)
3 Sums of 3 values in sample
Plotted position of first sum control point is 10+11+16 = 39
4 Actual item value, such as .011 inch, 11 ounce, or 11 points of hardness on Rockwell scale where 20 Rc might be considered as zero. Measured Value to 31 Rc
5 Sums of first two values in sample
Plotted position of first two values is 10+11 = 21
Scale of values
6 Values of first item of each sample measured
7 Dotted line is control limit for samples of 3 values. Control limit is located at value = 2.6 x average range. (See 6) For example 1, control limit is located at 2.6 x 2.4 = 6.2 from average range value. (see 9)
8 Difference between largest and smallest of 3 values in a sample. This difference is called the 'range'. Plotted position of first range control point = 14 - 10 = 4
Example 1
Sums
Ranges
Unheeded warning. Action should have been taken. (See 11)
These items are 1/2 unit under low specification !!
10 Is process capable of, and set correctly to meet specifications? Answer: Take 1/3 of solid line value on sum chart : 30 = distance from the solid line to a control limit, and compare resultant values to specifications. Illustration. - For example 1, process limits = (30 ± 21 = 14.5 x 7.4 = 10 ± 4.3 =5.7 and 14.3. Thus process limits are within specification limits of 5.5 and 14.5 indicating that process is properly centered and narrow enough.
Unheeded warning. Operator did nothing to correct process !!! (See 11)
Sample Numbers (or Point Numbers)
9 Example 1:
Average of 10 ranges equals the sum of 10 ranges divided by 10 = (4+1+2+1+4+1+3+2+4+2) ÷ 10 = 24 ÷ 10 = 2.4
!! Note !! Items are plotted in order of production (Manufacturing sequence)
IMPORTANT !!
A. Control limits are boundary lines for sum and range points. Let everything alone when all these points are within control limits. Adjust the process or take other corrective action only when a point falls beyond a control limit; Dont wait - TAKE ACTION IMMEDIATELY.
B. Control limits are calculated , a noted above only when ten or more sample numbers are available.
C. Numbers 3.1, 2.6, and 58 in boxes are always the same for any process provided three values are used for each sample number.
D. Do not hesitate to write to Hamilton Standard, East Hartford 8, Conn., Attention D. Shainin, Chief Inspector, if any questions arise or if your problem does not seem to be solved by such a chart.

Figure 3—**Back Side of Revised Lot Plot Form**

row the portions of a cell found by step i, in the direction corresponding to the sign of the i value, and draw a horizontal line labeled X.

SUMMARY OF EXPERIENCES

A summary of experiences brings out some of the psychological as well as material benefits of the Lot Plot.

General Comments

Most of the concerns employing the Lot Plot technique are pleased with the ease with which the picture of each plot can be interpreted by their own inspectors, their suppliers, and their customers. Scintilla Magneto Division of Bendix Aviation Corporation summed up the situation with

"Our experience with the Lot Plot method has shown that its use has wide application. Because the procedure can be easily explained to individuals with little or no statistical background, it is a simple matter to apply the Lot Plot procedure to a variety of situations.

"When the question is raised as to whether a tolerance can be held or not, the Lot Plot never fails to show the true condition existing. The simplicity of the procedure with provision for minimum sampling plus the graphical and mathematical interpretations make an ideal procedure for many types of quality control investigations."

Economy

While many had general statements on economy, the Collins Radio Company reported that the Lot Plot is saving it approximately 40% on direct inspection labor cost, and the Victor Adding Machine Company reports a savings in labor cost in excess of $20,000 in the first year of its operation.

Lot Plot Finds Missing Carpet

The lengths of Bigelow-Sanford Cushionlok carpet rolls are measured by running them on a cylinder and noting the number of revolutions. Each roll of carpet is so marked. An inventory of the lengths sold and those marked on the many rolls in storage fell far short of the total length noted on the original production records. A Lot Plot was made of the rolled out actual lengths of 50 random rolls at a cost of about $8,000. These were plotted as the percentage error of actual minus ticketed lengths (from the cylinder) over the actual lengths. Yes, there was a slippage between the carpet and the cylinder that was not appreciated. The Lot Plot enabled the company to pick the minimum amount of slippage expected in the entire lot and so re-mark the lengths to recover $16,800 without the danger of a series of complaints from customers about short lengths.

Lot Plots at One Plant Control Quality at Another

The Fuller Brush Company made a Lot Plot of 50 pitch diameters from a shipment of 494,000 threaded pieces. The clear bimodal distribution implied two machines set .002 inch apart, each capable of meeting specifications. The supplier, upon receiving their copy of the Lot Plot, confirmed the conclusion and thanked the company for the information as to the amount each machine had to be reset to make its product acceptable. The brush company says, "We have been using your Lot Plot method for approximately two years and we are more and more amazed each day by the accuracy of this method and the faith we can place in it."

York Corporation's suppliers have expressed appreciation for the Lot Plot analyses they received. Shown clearly was a shipment to shipment increase in the current needed to develop the required torque, and proof that the cutout time of a motor overload protector had a wider distribution at higher winding temperatures. In turn, York admits that Lot Plots revealed their gages for pressure controls always read 5 p.s.i. higher than their vendor's, and their voltmeter for checking relays was calibrated with divisions that were entirely too coarse.

Production Control

Lot Plots were not designed to replace control charts, but the Scovill Manufacturing Company runs a Lot Plot on each 4-hours' production from each of 10 to 20 machines of a small brass shell that is made in large quantities for numerous customers. Before they inaugurated this plan, they were under fire from their customers. There was too much opportunity for periodic causes of extra variation within machines and shifts among machines. They immediately got out of trouble. "Now, and I knock wood, we have been operating since September 27th 1949 without a single customer complaint."

Both the Pratt & Whitney Aircraft Division of United Aircraft Corp., and the Scintilla Magneto Division of Bendix Aviation Corp., use Lot Plots on successive batches of heat treatment.

At Pratt & Whitney:

1. To maintain a more constant quality assurance with a decrease in inspection or checking labor.
2. To accumulate data as an aid in establishing optimum time, temperature, and equipment conditions for different alloys and part numbers.
3. To provide data as an aid in reviewing troublesome specifications with Engineering.
4. To provide a basis for more rational dispositions of out-of-specification lots, i.e., correcting entire lot instead of sorting the bad from the good and rehardening them.

At Scintilla:

1. To give the heat treaters a score to shoot at.
2. To minimize the amount of inspection.
3. To reduce wear on expensive equipment.

Pratt & Whitney adds, "The results to date have been very favorable with an average of 200,000 piece-parts being processed monthly." Scintilla says, "The Lot Plot is sometimes a more efficient tool than the control chart for some processes. On high speed, short run jobs where control charts are difficult to set up and administer, the Lot Plot procedure can generally be used efficiently."

The Wallace Barnes Company, Division of Associated Spring Corporation, used a Lot Plot for checking out a pilot run on a new item for one of the Arsenals. The multimodal distribution led to a check with the set-up man. He had made an unnecessary change to the setting because of the results of his measurements on a few pieces.

Willys-Overland Motors, Inc., reports, "We use the Lot Plot very extensively for the analysis of operations as we can determine out-of-control conditions in a manner similar to an X, R chart."

The High Cost of Fixed Ideas

The Air Impeller Division of The Torrington Manufacturing Company found, with Lot Plots, that "perfect" balance of fans is more rare than barely acceptable balance, contrary to prior suppositions. It became clear that the operator cannot detect unbalance of a magnitude at all less than the natural tolerance and an im-

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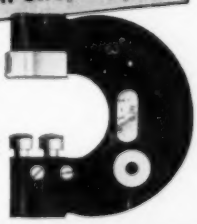

STANDARD GAGE CO., Inc., Poughkeepsie, N.Y.

provement in the balancing equipment was needed. From their experiences they comment:

"While the conclusions drawn are obvious in retrospect, the fact remains that they were clearly and quickly demonstrated by the routine of the Lot Plot as compared with the alternative methods of non-routine investigation from which conclusions are so often drawn by guesswork.

"We feel that the most powerful argument for the Lot Plot method is that it places in the hands of the inspector a means of determining quantitatively the quality of a lot of material by computations usually no more complicated than those of a bowling score and that in so doing it frees personnel having judgment and experience for more valuable pursuits. Like some theologians who feel that the workings of nature are more wonderful to contemplate than the occasional miracles, we feel that the routine benefits of Lot Plot are more wonderful than its 'miracles'."

The Whitney Chain Company detailed several important changes in their operations brought about through Lot Plots, and concluded, "Perhaps some of the things I have reported on would have been corrected without the use of the Lot Plot in other shops. But they had been going on here for fifty years more or less and I suspect we would have talked about it and done nothing for another fifty without the advantage gained from the use of the Lot Plot."

The checking of 60,000 new gas meters per year by Lot Plots is the plan of the Southern California Gas Company. One reason they have not gotten out of the experimental stage in their use of the plan is a difficulty in their own inspection routine disclosed by the Lot Plot plottings.

A hexagon punch for making sockets for a small set screw was found by a Lot Plot to give acceptable results at The Allen Manufacturing Company. The job had been held up for lack of tooling and this particular punch was among those that had been rejected to customary standards.

Versus 100% Inspection

A heavy rolled wire job at the Wallace Barnes Company required 100% sorting because a small percentage continuously fell outside of one limit. Lot Plots located the particular operation that caused the difficulty and indicated the amount and type of correction needed. On their last order for 250,000 parts the Lot Plots showed that only 10,000 parts had to be screened.

The Victor Adding Machine Co npany found that 100% inspection was now no longer necessary on the thickness of raw strip steel, since they began to use Lot Plots. Also contrary to their specifications for thickness of different lots to different tolerance ranges, the steel often came in to a larger or much smaller spread. The steel is thus classified by the natural tolerance of the lot for the manufacture of appropriate parts. The plan has also completely eliminated the possibility of over-sized material getting into a blanking operation, which often causes die breakage. It was proved that under the 100% inspection previously used, over-sized stock was overlooked.

The Hedman Company echoes with "When buying in today's steel market we sometimes use a Lot Plot to determine the suitability of a particular lot of steel when a close tolerance on thickness is required."

The extremely close tolerance dimensions on valve stems and on valve tappet rollers at the Pratt & Whitney Division of United Aircraft Corp., have been checked for some time on a daily requirement of over 1,000 pieces of each part. They report "It has been necessary to reject occasional lots of these parts based on Lot Plot results but no assembly difficulties or field service troubles have been reported since the plan was placed in operation. Formerly, 100% inspection was required for each of these drawing requirements; therefore, the reduction in inspection time has been very substantial."

Versus Attribute Sampling

The Esterbrook Pen Company reports "There are several items that we purchase in large quantities which when sampled by attributes require a sample of 750 pieces. We now use a sample of 50 using the Lot Plot, and when the sample is rejectable, estimate the percentage not acceptable. A decision is then made as to acceptance or rejection of the shipment. As I said once before—the damn thing really works! Besides economy, the accuracy of sampling by Lot Plot is just as accurate as by attributes if not more so."

The Allison Division of General Motors Corp. ran instruction sessions on statistical quality control for some of their employees and used a lot of 1,000 pieces, with carefully measured and recorded diameters, as a lot from which to draw test samples. The action of single, double, sequential, and Lot Plot sampling was compared. The study included the amount of information obtained with regard to the true condition of the lot and the protection available by each method. Allison concludes its interesting story with "The results of the Lot Plot chart were amazing. Those who had accepted it during the previous session were now willing to accept it with even greater assurance. The two who had been skeptical readily admitted that here was a technique that would be very beneficial to the Inspection Departments. The group was advised that they could not expect the accuracy found in the example each time the technique was used. However, if properly used, they could expect it to give more revealing information than could be obtained from any single, double, or sequential sampling plan."

A Happy Accident

Some time ago an attempt was made to demonstrate to the Management of the Underwood Corporation the dependability of this technique. A Lot Plot was made from a lot of 25,190 pieces. The charts which are part of the Lot Plot method predicted from the plot that the lot would contain 10% defective parts. The result of the subsequent 100% sorting proved there was, in fact, exactly 10% or 2,519 parts defective. Their Chief Inspector adds "It so happened that this particular sampling was performed under controlled conditions."

More conservatively, the Delco-Remy Division of General Motors Corp., announces, "The actual number of defective pieces found in rejected lots after screening has always been very close to the percentage outside specification limits shown on our Lot Plot Charts."

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Influencing Customers

Perhaps it is a characteristic of the spring industry or perhaps it is just another coincidence but two divisions of the Associated Spring Corp., the Wm. D. Gibson Company and Wallace Barnes Company bring out, in turn, "We do use the Lot Plot in quite a few of our processes; however, it is chiefly used in our sampling of outgoing inspection where a copy of the results is forwarded to the customer. We find that this procedure has given us not only a better understanding with our customers, but also, a method by which we are able to compare test results." And "Our experience with the Lot Plot has been such that we place our utmost confidence in its results and readily abide by its decisions. We have also found that in corresponding with customers in regards to changes, etc., reference to the Lot Plot has often been the wedge needed to convince them of our need for increased tolerance."

Also, the American Coil Spring Company says, "We do use your method frequently in making decisions as to disposition of doubtful lots of springs in process and in final inspection. We find the Lot Plot form easier to "sell" than some others we have tried. In two specific cases of different types of parts we were able to get customer's acceptance of previously rejected lots as a result of the use of the Lot Plot form. On the whole we find the Lot Plot plan tells us what we want to know as soon as possible."

Buttons and Bows

The Shenango Pottery Company complains that when their cups and saucers don't fit properly there is usually a demand for new design for one or the other of the two components. It got to the point with their hotel trade where they were manufacturing 435 different cups and 109 different saucers. The Lot Plot has given them an economical way of recognizing the extent of variation and the percentage of assemblies that will interfere. They are now well on the way to reducing their line by $^2/_3$.

The Scovill Manufacturing Company uses Lot Plots for the acceptance of such diverse items as pearl inserts for grip fasteners, tacks for work garment buttons, and mirrors for cosmetic containers. And to think that the Lot Plot was designed to reduce the risk of defective material getting by 100% inspection in an aircraft propeller machine shop!

Editorial Note: *The following three papers serve to contribute further to the general theme of Mr. Shainin's report and together with it are presented as a unit "package" on Lot Plot.*

Modification of the Lot Plot Method of Acceptance Sampling

ROBERT L. ASHLEY

Scintilla Magneto Division, Bendix Aviation Corporation*

DORIAN SHAININ'S Lot Plot method of acceptance sampling has been a boon to those industries doing a large amount of this type of acceptance sampling. Probably no sampling technique gives as much information for so small an amount of inspection.

His plan utilizes a coded frequency distribution of 50 pieces chosen at random from a lot. The measurement of these 50 pieces gives an insight into the variation of the lot that attribute sampling is incapable of doing. Quite often the Plot of these 50 pieces gives a normal distribution well within the specification and the lot is accepted without further computations. Equally as often it is necessary to determine the average and lot limits for the Plot.

Mr. Shainin computes the average by using the coded sums of ten groups, each containing five pieces. These sums are multiplied by .2 and the average of the products determined. This average is the desired $\overline{X}$.

The 3σ limits are determined by using the Pearson-Tippett method of estimating the standard deviation from the range. The ranges for these same ten groups are determined and $\overline{R}$ computed by dividing the sum of the ranges by ten. A successful estimation of 3σ is then obtained by multiplying R by 1.3.

I found that by designing a Lot Plot form that incorporates the usual method of computing averages and standard deviation, I was able to obtain the desired information much more rapidly. This Lot Plot form differs in a few respects from the standard form. (See Figure 1)

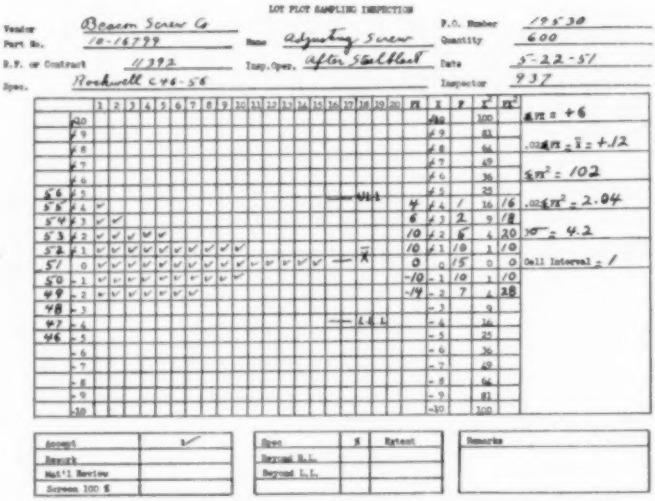

Figure 1—**An Example of a Completed Modified Lot Plot Form**

DESCRIPTION OF MODIFIED LOT PLOT FORM

1. All cell data are recorded directly opposite the cell values. Using offset cell frequencies is often confusing to the inspector; this is especially true when sums and ranges are to be computed.
2. At the far right side of the frequency chart there are five columns headed: FX, X, F, X^2, and FX^2. The X column contains the same cell values as occur in the second column at the left of the chart. The X^2 column contains these values squared. Column F contains spaces for the frequencies to be written in. Columns FX and FX^2 contain spaces for the products of the frequencies times the cell values and the frequencies times the cell values squared to be written in.
3. The top row is numbered 1, 2, 3, etc. to facilitate finding cell frequencies.
4. The block at the right of the frequency chart contains places to enter totals and record calculations.

ΣFX = ———— Sum of the products of the cell values, times their frequencies.

$.02 \Sigma FX$ = ———— Equivalent to dividing ΣFX by 50, the usual method of determining $\overline{X}$.

ΣFX^2 = ———— Sum of the products of the cell values squared, times their frequencies.

$.02 \Sigma FX^2$ = ———— Equivalent to dividing ΣFX^2 by 50.

3σ = ———— Read directly from Chart 1.

Cell Interval = ———— Difference in actual measurements between adjacent cells.

PROCEDURE

The first five pieces of the sample of 50 are measured and used to center the distribution around zero. This plan does not use sums and ranges so there is no need to treat the remaining 45 pieces as individual samples of five pieces each. They are merely measured and checks (√) placed opposite the correct cell values.

*Mr. Ashley is now Statistician for the New York State Department of Public Health.

.02 ΣFX²	X̄ Values to Nearest Tenth																								
	0.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5
0.0																										
.5	2.1	2.1	2.0	1.9	1.7	1.5	1.1	.3																		
1.0	3.0	3.0	2.9	2.9	2.7	2.6	2.4	2.1	1.8	1.3																
1.5	3.7	3.7	3.6	3.6	3.5	3.4	3.2	3.0	2.8	2.5	2.1	1.6	.7													
2.0	4.2	4.2	4.2	4.1	4.1	4.0	3.8	3.7	3.5	3.3	3.0	2.7	2.2	1.7	.6											
2.5	4.7	4.7	4.7	4.7	4.6	4.5	4.4	4.3	4.1	3.9	3.7	3.4	3.1	2.7	2.2	1.5										
3.0	5.2	5.2	5.2	5.1	5.1	5.0	4.9	4.8	4.6	4.4	4.2	4.0	3.7	3.4	3.1	2.6	2.0	1.0								
3.5	5.6	5.6	5.6	5.5	5.5	5.4	5.3	5.2	5.1	4.9	4.7	4.5	4.3	4.0	3.7	3.4	2.9	2.3	1.5							
4.0	6.0	6.0	6.0	5.9	5.9	5.8	5.7	5.6	5.5	5.4	5.2	5.0	4.8	4.6	4.3	4.0	3.6	3.2	2.6	1.9						
4.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.0	5.9	5.8	5.6	5.4	5.2	5.0	4.8	4.5	4.2	3.8	3.4	2.8	2.1	.9				
5.0	6.7	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.3	6.1	6.0	5.8	5.7	5.5	5.2	5.0	4.7	4.4	4.0	3.5	3.0	2.3	1.2			
5.5	7.0	7.0	7.0	7.0	6.9	6.9	6.8	6.7	6.6	6.5	6.4	6.2	6.0	5.9	5.6	5.4	5.1	4.8	4.5	4.1	3.7	3.1	2.4	1.4		
6.0	7.3	7.3	7.3	7.3	7.2	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.4	6.2	6.0	5.8	5.6	5.3	5.0	4.6	4.2	3.8	3.2	2.5	1.5	
6.5	7.6	7.6	7.6	7.6	7.6	7.5	7.4	7.4	7.3	7.2	7.0	6.9	6.7	6.6	6.4	6.2	6.0	5.7	5.4	5.1	4.7	4.3	3.9	3.3	2.6	1.5
7.0	7.9	7.9	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.5	7.3	7.2	7.1	6.9	6.7	6.5	6.3	6.1	5.8	5.5	5.2	4.8	4.4	3.9	3.3	2.6
7.5	8.2	8.2	8.2	8.2	8.1	8.1	8.0	7.9	7.9	7.8	7.6	7.5	7.4	7.2	7.1	6.9	6.7	6.4	6.2	5.9	5.6	5.3	4.9	4.5	4.0	3.4
8.0								8.2	8.1	8.0	7.9	7.8	7.7	7.5	7.4	7.2	7.0	6.8	6.5	6.3	6.0	5.7	5.3	5.0	4.5	4.0
8.5											8.2	8.1	8.0	7.8	7.7	7.5	7.3	7.1	6.9	6.6	6.4	6.1	5.7	5.4	5.0	4.5
9.0													8.3	8.1	8.0	7.8	7.6	7.4	7.2	7.0	6.7	6.4	6.1	5.8	5.4	5.0
9.5															8.2	8.1	7.9	7.7	7.5	7.3	7.0	6.8	6.5	6.2	5.8	5.4
10.0																	8.2	8.0	7.8	7.6	7.3	7.1	6.8	6.6	6.2	5.8
10.5																		8.3	8.1	7.9	7.6	7.4	7.1	6.8	6.5	6.2
11.0																				8.2	7.9	7.7	7.4	7.2	6.9	6.5
11.5																					8.2	8.0	7.7	7.5	7.2	6.9
12.0																						8.3	8.0	7.8	7.5	7.2
12.5																							8.3	8.1	7.8	7.5
13.0																								8.3	8.1	7.8
13.5																									8.3	8.1

The total frequency in each cell row is entered in column F. The cell values are multiplied by their frequencies and the products entered in column FX. The cell values squared are multiplied by their frequencies and the products entered in column FX^2. Columns FX and FX^2 are summed and the results entered in spaces marked ΣFX and ΣFX^2 at the right of the chart. X is found from Chart 1 as explained below.

HOW TO USE CHART 1

Chart 1 is merely the tabulation of 3σ values as determined by entering given combinations of ΣFX^2 and X in the formula

$$3\sigma = 3\sqrt{\Sigma FX^2/50 - X^2}.$$

The chart is limited to $\overline{X} = 2.5$ because a normal distribution centered at zero by the estimation from the first 5 pieces rarely has an average for 50 pieces beyond 2.5 cells from zero. Values for 3σ much greater than 8 cells were not included because they would represent too fine a cell interval.

Chart 1—3σ Values

To find 3σ from Chart 1, locate on this chart the $\overline{X}$ column closest to the X, calculated to the nearest tenth, on the Lot Plot form and go down this column to the row whose $.02\,\Sigma FX^2$ value at the extreme left of the chart is closest to the $.02\,\Sigma FX^2$, calculated to the nearest five tenths, on the Lot Plot form. The value recorded in this cell of intersection is the estimated 3σ for the distribution. Interpolation is seldom necessary, but may be easily accomplished if it seems warranted.

An estimate of the upper lot limit (ULL) in cells is then obtained from $\overline{X} + 3\sigma$, and similarly the lower lot limit (LLL) may be estimated from $\overline{X} - 3\sigma$. The X, ULL, and LLL points may then be marked in and labelled on the Lot Plot form for comparison with the specifications.

CONCLUDING REMARKS

The average obtained by the method of this Modified Lot Plot form is obviously the same as if sums of ten groups of five each had been used (Shainin's method). The estimated lot limits seldom vary by more than .2 cell from those estimated by use of $\overline{R}$. This small variation, coupled with the fact that 3σ limits include only about 4% more of a normal distribution than do 2σ limits, makes the results of the two methods equivalent for all practical purposes.

Shainin's Chart A is equally effective using these limits, although it should be emphasized that the modification of the Lot Plot Method proposed in this paper for estimating lot limits is applicable only to normal-appearing distributions. However, having X and X^2 printed on the Lot Plot form makes the computations for Charts C_1 and C_2 easier. These printed values should be cut out of a blank form and shifted as necessary on filled-in Lot Plots to line up the printed "zero" with the mode cell. (Charts A, C_1, and C_2 are in the original Lot Plot paper, this journal, July 1950).

Figure 1 gives an example of a modified Lot Plot form filled in according to the directions discussed in this paper.

A Convenient Short Cut in the Use of Lot Plot

RICHARD WILSON
Formerly with The Bristol Company*

OFTEN in industry, valuable information concerning the quality of manufactured or purchased material is not calculated because of the excessive time required to collect and compute the necessary statistics.

The Lot Plot system has been advanced as a systematic and time saving method of establishing dispersion limits for a frequency distribution from a sampled lot. On the assumption that the mechanics, advantages, and applications of that system are known, this paper will outline an alternate method of obtaining the limits which will simplify and speed up the work involved.

Considering the equation for standard deviation $\sigma = \sqrt{\Sigma(X-\bar{X})^2/n}$ and its equivalent $\sigma = \sqrt{\Sigma FX^2/n - \bar{X}^2}$ it can be seen that if $\bar{X}$ can be made sufficiently close to zero, $\bar{X}^2$ can be eliminated from the equation without serious error, leaving $\sigma = \sqrt{\Sigma FX^2/n}$. If the position of the cell containing the mean is determined and the center of it is set equal to zero, with the center of the cells on either side being 1, 2, 3, etc., then $\bar{X}$, which lies in the mean cell, cannot deviate from zero by more than half a cell width. Thus the largest value that $\bar{X}^2$ can have is $(\frac{1}{2})^2$ or .25 squared cell units. For practical values of 3σ, the error incurred by ignoring this quantity is not at all excessive. For a distribution of fifty observations having 3σ limits of ± five cells, the maximum error would be about one-fifth of a cell. The amount of the maximum error decreases considerably for wider dispersions and, conversely, increases for narrower dispersions. It can readily be seen that for small values of ΣFX^2 the error could not be tolerated. A justification for the use of this equation and a method of correction is outlined later.

To make this a practical method for computing dispersion limits, a quick and simple scheme for determining $\bar{X}$ and FX^2 is necessary. To do this we have drawn two trans-

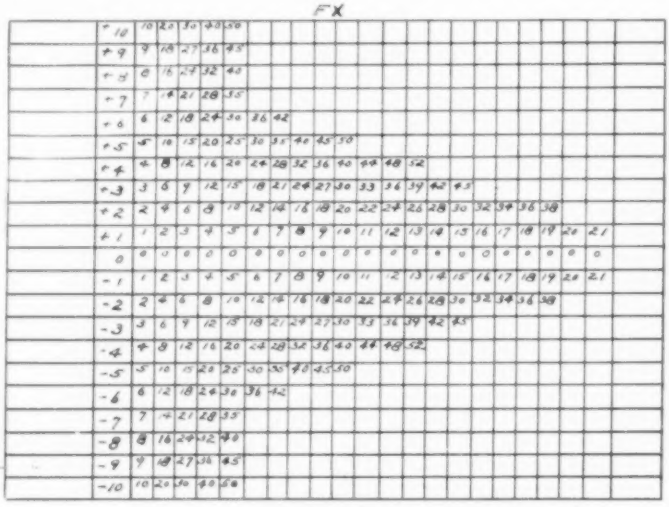

Figure 1—**Lot Plot Template for FX Values**

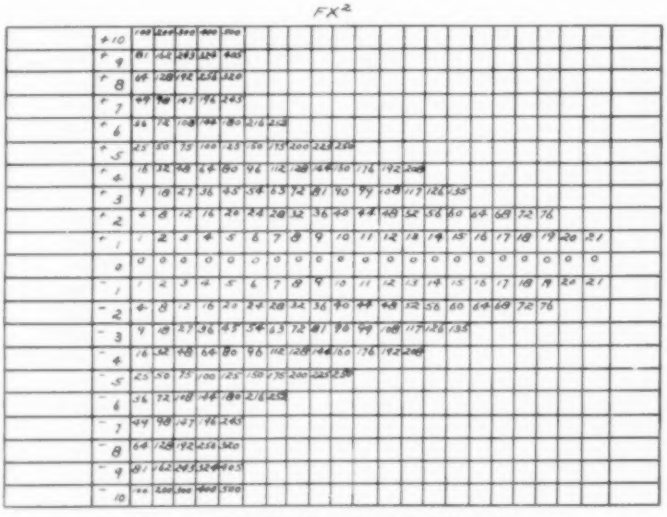

Figure 2—**Lot Plot Template for FX² Values**

*This paper was submitted by Mr. Wilson and recommended for publication under his name by Mr. J. F. Graecen, Chief Inspector of The Bristol Company, who writes, "We use only this in the inspection of the pitch diameter of our socket screws. We think the method is sufficiently accurate and gives us an adequate quality picture. I feel certain it was in part responsible for the low customer returns we had in 1950. During that year we shipped 68 million screws and received only 1932 back from customers."

TABLE 1—**Approximate 3σ Values for Sample Size 50 where $3\sigma = 3\sqrt{\Sigma FX^2/50}$**

ΣFX^2	3σ	ΣFX^2	3σ	ΣFX^2	3σ	ΣFX^2	3σ
50	3.00	100	4.24	200	6.00	300	7.36
55	3.14	110	4.45	210	6.14	310	7.48
60	3.28	120	4.65	220	6.28	320	7.60
65	3.42	130	4.84	230	6.42	330	7.72
70	3.56	140	5.02	240	6.56	340	7.83
75	3.67	150	5.19	250	6.70	350	7.94
80	3.80	160	5.36	260	6.84	360	8.05
85	3.91	170	5.52	270	6.97	370	8.16
90	4.02	180	5.68	280	7.10	380	8.27
95	4.14	190	5.84	290	7.23	390	8.38
100	4.24	200	6.00	300	7.36	400	8.48

parent templates of the graph section of a standard Lot Plot form. On one of the templates, for each value of X from +10 to −10 the value of FX was placed in the appropriate square (Figure 1). In a similar manner the values of FX^2 were placed on the other template (Figure 2).

The procedure to be followed is now obvious. Place the FX template over the distribution with its zero cell over a cell on the plot near the center of the distribution. Values of FX can be noted directly from the template. The position of X can then be determined. At this point it is advisable to draw in the X line. Place the FX^2 template over the distribution with its zero cell over the mean cell, note and sum the values for FX^2. Using the simplified equation $3\sigma = 3\sqrt{\Sigma FX^2/n}$ the 3σ limits can be calculated with a slide rule, from a graph, or, where a standard sample size is used, from a table that has been made up to give values of 3σ directly from ΣFX^2.

Experience has shown that time can be saved using this method, especially if advantage is taken of the fact that it is not necessary to record the sequence of observations. A variety of methods can be developed to allow an inspector to group observations without interfering seriously with the inspection routine. All of the tabulations can then be made at one time.

It was pointed out before that for low values of FX^2, neglecting $(-\bar{X}^2)$ in the equation $3\sigma = 3\sqrt{\Sigma FX^2/n - \bar{X}^2}$ leads to considerable error. It may be desirable to minimize this error by a slight correction. $-\bar{X}^2$ can be included in the equation if X is beyond a predetermined fraction of a cell, depending on the accuracy required. (One-tenth of a cell would be a safe fraction beyond which $-\bar{X}^2$ should be included.)

For our purposes, we have made up a table (Table 1) giving values of 3σ for values of ΣFX^2 in steps of five from 50 to 100 and in steps of ten from 100 to 400, using a standard sample size of fifty and the equation $3\sigma = 3\sqrt{\Sigma FX^2/n}$. Values of 3σ much greater than 8 cells would represent the selection of too fine a cell interval.

This method of computing dispersion limits is useful only where the distribution is normal.

How Effective Is Lot Plot?

A Report of an Experiment Conducted by the Allison Division GMC and the Indianapolis Section, ASQC

IN TEACHING SQC methods, the use of actual pieces is preferred whenever possible. At one time 1000 pins which had been made consecutively by an automatic lathe were used for classroom demonstrations. These pins were placed in a drum and thoroughly mixed. Random samples were then drawn from this drum by one student and the pins in these samples measured and recorded by another student. Data collected in this manner were used for teaching the principles of control charts and other sampling instruction.

Some time after these pins had been in use as just described, the Aircraft Industries Association circulated a letter proposing that some type of nation-wide program be set up to study the effectiveness of the Lot Plot technique. After receiving

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a copy of this letter, each of the 1000 pins was very carefully measured and a bowl of chips was made up with the chips numbered to correspond to the actual distribution of the pins as shown by the histogram in Figure 1. This bowl of chips was then used to represent ten consecutive lots of 1000 items each. From each such lot a random sample of 50 was drawn, and predictions of lot characteristics were made as directed by the Lot Plot Plan. The respective lot distribution curves predicted by these samples were then compared with the theoretical curve based on the known parameters of the 1000 pins. A copy of this experiment with the results obtained was forwarded to AIA in response to its proposal.

Figure 2 summarizes in both graphical and numerical form the results of this experiment. Arbitrary specifications of 4.9 and —5.9 were adopted. UCL and LCL represent the upper and lower theoretical and predicted 3-sigma limits on individuals. It may be noted that these are 7.813 and —8.867 respectively for the universe of 1000 pins, whereas this universe actually contained one pin that measured 8 and two that measured —9. The last two rows in Figure 2 represent the theoretical and sampling predictions of the percentages outside the specifications of 4.9 and —5.9.

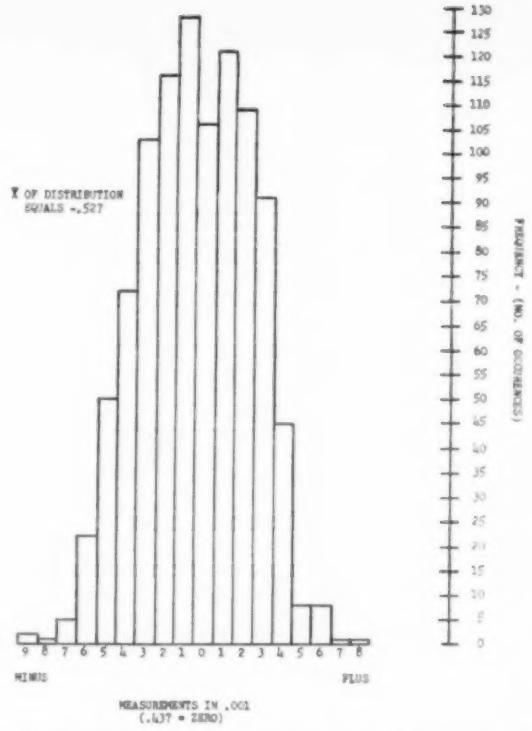
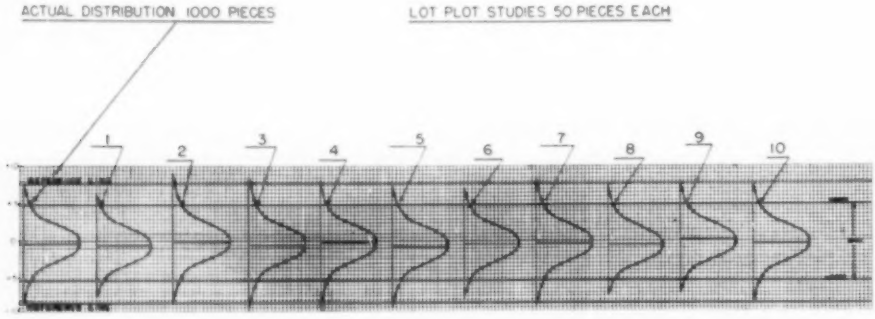


Figure 1—**Histogram of the Frequency Distribution of 1000 Pin Diameters**



$\bar{X}$, -.527	-.8	-.08	-.72	-.36	-1.12	-.6	.38	-.18	.42	-.62
σ, 2.78	2.43	2.99	3.08	2.74	2.65	2.56	2.90	2.56	2.52	2.73
UCL, 7.813	6.48	8.89	8.51	7.96	7.43	7.07	8.33	7.49	7.96	7.57
LCL, 8.867	8.08	9.05	9.95	8.68	9.67	8.27	9.09	7.85	7.12	8.81
%+, 2.6	1.0	4.8	3.5	2.8	1.2	1.6	3.5	2.4	3.8	2.2
%-, 2.7	1.8	2.7	4.7	2.2	3.6	2.0	2.9	1.3	0.7	2.7

Figure 2—**Summary and Comparison of Ten Lot Plot Studies vs. a Known Lot Distribution**

Rough-and-Ready Statistical Tests*

W. ALLEN WALLIS

University of Chicago

1. SIGN TEST

Quick-and-dirty, or rough-and-ready, tests are typified to my mind by the sign test. It is certainly quick and ready, and it is rough and dirty in that for publication people usually prefer something more elaborate—though I am sure that this is often superfluous.

Example 1.1

Let me explain the sign test by a characteristic example. Recently a statistician talked with me about analyzing some data that were supposed to show whether male and female employees differ in their attitudes toward a certain company. He had questions about t-tests, analysis of variance, homogeneity of variances, and so on. I didn't know the answers to all of his questions, but as an inveterate sign tester I could see that there definitely was a difference between the sexes.

Each sex had been divided into six groups, three length-of-service categories for each of two races. The Negro short-term males were less favorable to the company than were the Negro short-term females. The white short-term males were also less favorable than the white short-term females. In fact, all six pairs showed the males less favorably disposed toward the company than the corresponding group of females.

Now suppose that actually the two sexes are equally favorable. Then in each comparison it would be a fifty-fifty chance which one happened to look less favorable. So in six comparisons, as in six tosses of a coin, there would be only one chance in 32 that all would come out alike. I am a five-per-center or two-sigma man on significance levels, at least in rough-and-ready work, so I decided that there definitely was a sex difference.

Example 1.2

Another man, a lawyer this time, came in with a stack of about 800 cards on which he had some data about lawyers' incomes and other matters. A question arose as to whether there is a correlation between age and amount of education. We decided to get a rough idea quickly by taking 20 cards at random and plotting a scattergram. When we plotted the 20 points, the lawyer complained that the sample was not random, because 65 percent of our sample exceeded the median age for all 800, which he had computed earlier. Again the sign test came in handy. If each of our 20 had been equally likely to be above or below the median, the chance of getting a division as uneven as 13 to 7 would be about 1 in 4. So there was no cause for alarm; we were well below the 2σ or 5 percent level.

To apply the sign test, we proceed as follows:

Let N be the number of observations, each of which we have classified as + or −.

Let X be the number of occurrences of the more numerous of the two signs.

Then $[(2X - 1)/\sqrt{N}] - \sqrt{N}$ expresses the departure of X from N/2 in standard deviations.

If this exceeds 1.96, or roughly 2, the result is significant at the 5 percent or 2σ level.

If we want the actual probability we look in a table of the normal curve, using both tails. In example 1.2 (lawyers), this gives a probability of 0.2636, whereas the exact probability calculated from the binominal distribution is 0.2631. In Example 1.1 (sexes), the normal curve gives a probability of 0.0412, whereas the exact probability is 0.0312. At any significance level likely to be used, say 10 percent or less, the normal approximation is satisfactory no matter how small the sample.

Example 1.3

As a final application of the sign test, consider a before-and-after experiment. Recently I gave an examination which included the following assertion to be marked true or false: "A sample that includes 5 percent of its lot is much more reliable as an indicator of lot-quality than a sample which includes only 0.1 percent of its lot." The principle involved had not been discussed in class, but had been covered in reading assignments. In the next quiz after the topic had been discussed in class, I included the same question. The results are shown in the following table:

After	Before		Total
	True	False	
True	12	3	15
False	10	9	19
Total	22	12	34

Did the discussion do any good? Clearly 21 students were unaffected, so the question is whether there were significantly more converts from true to false than there were backsliders from false to true. There *were* more, or we could stop the statistics right here, and not ask whether there were *significantly* more. Applying the sign test with N = 13 and X = 10 we find 1.664 as a unit normal deviate. Here we want a one-tail test, for which the 5 percent critical level is 1.645; so I just barely got in under the 5 percent wire. The normal distribution shows a probability of 0.048; the exact probability is 0.046.

Incidentally, I have included this example because it is one that people commonly analyze wrong, as well as because it is a useful application of the sign test. Many people would make the mistake of comparing the total column with the total row, as if they represented two independent samples. They represent the same sample twice, which is a far cry from independence.

Example 1.2 (lawyers) involved comparing a sample average with a preconceived notion of the average of the population. Examples 1.1 (sexes) and 1.3 (quiz) involved comparing averages, where the data have come to us in pairs. Each individual contributes one + or − sign to the comparison of the averages.

*A paper presented at the Fifth Annual Convention of the American Society for Quality Control, Cleveland, May 24, 1951.

2. ANALYSIS OF VARIANCE BY RANKS

Example 2.1

Suppose we want to compare more than two averages, and that again the data come to us in sets. For example, in inspecting the clerical operations involved in a certain sampling procedure, Rosander, Blythe, and Johnson recorded the percentage of errors by day of the week for eight weeks, as shown in Table 2.1. Is there any consistent variation among the days? In other words, are the average error rates really higher some days than others, or is the variation in the observed averages a matter of chance?

A rough-and-ready answer to this question will be obtained if we rank the days of each week, and then determine whether certain days have consistently high or low ranks, as in Table 2.2.

TABLE 2.2—**Weekly rankings of error rates in selecting a sample**

Week	Mon	Tue	Wed	Thu	Fri
1	2	4	3	5	1
2	5	4	2	1	3
3	5	2	4	1	3
4	5	4	3	2	1
5	5	4	1	2½	2½
6	3	4	5	2	1
7	4	1	2	5	3
8	1	2½	2½	4½	4½
Sum	30	25½	22½	23	19
Square	900	650¼	506¼	529	361

S = sum of squares = 2946.5
M = number of rankings = 8
R = number of ranks = 5

Then we compute

$$\chi^2 = [12S/MR(R+1)] - 3M(R+1)$$
$$= [(12)(2946.5)/(8)(5)(6)] - (3)(8)(6)$$
$$= 3.3.$$

Since the 5 percent level of χ^2 for 4 (= R − 1) degrees of freedom is 9.5, this result is not significant; the probability is, in fact, just under ½. Thus there is no evidence of a day-of-the-week effect on accuracy. It might be, of course, that there really is such an effect, but that it is obscured in these data by other effects. The paper from which the data came mentions, for example, that the error rate tended to jump following a shutdown, or when new or less experienced people participated in the work, and that these effects may have obscured any day-of-the-week effect there is. These possibilities could, of course, be analyzed statistically.

TABLE 2.1—**Errors made in selecting a sample (percent)**

Week	Mon	Tue	Wed	Thu	Fri	Weighted Mean
1	6.5	9.5	8.0	11.0	6.3	8.1
2	12.4	10.9	6.7	4.7	8.4	7.3
3	5.0	3.2	4.5	2.7	3.9	3.7
4	10.4	7.8	7.1	3.9	3.5	5.9
5	5.1	4.8	3.3	4.1	4.1	4.4
6	3.9	5.2	10.0	3.8	3.0	5.3
7	5.2	4.2	4.5	7.1	5.0	5.1
8	3.5	4.2	4.2	5.4	5.4	4.6
Weighted Mean	5.6	5.8	5.9	4.9	5.1	5.4

This method of comparing a set of means is not only quicker and easier than the usual analysis of variance, but may actually be superior. In this illustration, for example, the variability of error rates probably is not uniform throughout the table, as would be assumed in a standard variance analysis.

A limitation of the method is that it is appropriate only when the data come in natural clusters, each cluster containing one observation from each of the groups we want to compare. If we simply had data on eight Mondays, eight Tuesdays, etc., but no grouping into weeks, we could not use this method.

3. GROUPING OF ELEMENTS

A rough-and-ready method of comparing two means when the data do not come in pairs is to arrange all the observations from both samples in a single list according to size, then replace each observation by A or B, according to which sample it comes from. We base our test on the number of groups, or "runs", of A's and B's. If n_1 and n_2 denote the sizes of the two samples, $N = n_1 + n_2$, and z is the number of groups ("runs") found, we calculate

$$\frac{N(z - 0.5) - 2n_1n_2}{\sqrt{\frac{2n_1n_2(2n_1n_2 - N)}{N - 1}}}.$$

If n_1 and n_2 are not too unequal, this can be regarded as a unit normal deviate. The probability should be based on the negative tail only of the distribution, since a difference in the means, in either direction, produces too few runs. Thus the 5 percent point is −1.645. Should we be interested in too many runs, (z − 0.5) in the formula above should be replaced by (z − 1.5), and the positive tail of the distribution used.

It must be admitted that this test is not very powerful. That is, unless the samples are large, it is not likely to detect a difference in the means unless the difference is large relative to the variability. On the other hand, the test is somewhat affected by any difference between the populations. That is, if the populations have the same mean but different standard deviations, skewnesses, or other characteristics, this test might reveal that they differ.

Example 3.1

Brownlee gives the following data on the results of two alternative methods of technical chemical analysis:

Method A	Method B
95.6	93.3
94.9	92.1
96.2	94.7
95.1	90.1
95.8	95.6
96.3	90.0
	94.7

To determine whether the two methods differ systematically we arrange all 13 observations in order according to magnitude:

Rank	Analysis	Method
1	90.0	B
2	90.1	B
3	92.1	B
4	93.3	B
5½	94.7	B
5½	94.7	B
7	94.9	A
8	95.1	A
9½	95.6	A
9½	95.6	B
11	95.8	A
12	96.2	A
13	96.3	A

The horizontal lines in the "method" column indicate the ends of groups. Interchanging the fifth and sixth values or the ninth and tenth, which are ties, will not alter the number of groups, which is 4. Had the order assigned to the ties mattered, we would have put each tied group into each possible order, counted the number of runs for each order, and averaged the results. We need not be concerned if this should give a fractional number of runs.

Here we have $z = 4$, $n_1 = 6$, $n_2 = 7$, and $N = 13$, so

$$\frac{45.5 - 84}{\sqrt{(84)(71)/12}} = -1.727$$

is our unit normal deviate. This is significant at the 5 percent level. The probability indicated by the normal curve is 0.0421; the exact probability is 0.0425.

Example 3.2

The grouping test can be applied to arrangements in time and space. Suppose that of 100 consecutive points on a control chart, 62 are above the process average and 38 below. The sign test indicates a real tendency for the average to rise, for

$$\frac{(2)(62) - 1}{\sqrt{100}} = \sqrt{100} - 2.3.$$

A question arises as to whether the above-average items tend to come in bunches. There are found to be 38 groups, so the unit normal deviate is

$$\frac{100 \times 37.5 - 2 \times 62 \times 38}{\sqrt{\frac{(2 \times 62 \times 38) \times (2 \times 62 \times 38 - 100)}{99}}} = -2.05.$$

This is significant at the 5 percent level, or even at the 2 percent level, which suggests that the higher average is caused by some factor which operates intermittently.

Grouping tests can also be used when there are several groups. If there are N observations divided into three or more groups, let n_i denote the number in the i-th group, so that $\Sigma n_i = N$. We arrange all N observations in order, mark each one A, B, C, D, . . . , and count the groups, calling the result z. Now z is approximately normally distributed with mean

$$E(z) = \frac{N(N+1) - \Sigma n^2}{N}$$

and standard deviation

$$\sigma_z = \sqrt{\frac{N(N+1)\,\Sigma n^2 + (\Sigma n^2)^2 - 2N\,\Sigma n^3 - N^3}{N^2(N-1)}}.$$

These formulas are not complicated to compute; they depend only on N, Σn^2, and Σn^3. Again, we are ordinarily interested only in the negative tail of the distribution. As a continuity correction, we add 0.5 to z; should we be interested in the possibility of too many groups, we would subtract the 0.5.

Example 3.3

Brownlee gives the following data on through-puts obtained from certain equipment before failure through corrosion, when the units put through came from three different foundries:

Foundry	Throughput obtained
A	84, 60, 40, 47, 34
B	67, 92, 95, 40, 98, 60, 59, 108, 86
C	46, 93, 100

Arranging all 17 observations in order, we obtain Table 3.3.

TABLE 3.3

Rank	Through-put	Foundry
1	34	A
2½	40	A
2½	40	B
		—(2½)
4	46	C
5	47	A
6	59	B
7½	60	A
7½	60	B
9	67	B
		—(3)
10	84	A
11	86	B
12	92	B
13	93	C
14	95	B
15	98	B
16	100	C
17	108	B

Here N = 17 and we have either 13 or 14 groups, depending on the order of the second and third observations, so we take z as 13.5. Since $n_1 = 5$, $n_2 = 9$, and $n_3 = 3$, we find $\Sigma n^2 = 115$, $\Sigma n^3 = 881$. So

$$E(z) = \frac{17 \times 18 - 115}{17} = 11.2353$$

and

$$\sigma_z = \sqrt{\frac{17 \times 18 \times 115 + (115)^2 - 2 \times 17 \times 881 - (17)^3}{(17)^2 \times 16}} = 1.7117.$$

Since z exceeds E(z), there clearly is no evidence of a difference among the three groups. If we check the possibility of too many groups, we have as our unit normal deviate

$$\frac{13 - 11.2353}{1.7117} = +1.03$$

giving a probability of about 0.15, which is not particularly suspicious—especially since we did not decide to make this test until we saw that it might approach significance. Brownlee's analysis of variance for these data also failed to show significant variation among the foundries.

4. COMPARISON OF MEAN RANKS WITH NON-PAIRED OBSERVATIONS

Rank analysis of variance of the kind discussed in Section 2 can be used only if the observations are in pairs (triples for comparing three groups, quadruples for four, etc.), one from each group. Data like those of Examples 3.1 and 3.3 can, however, be analyzed readily by an alternative ranking method. This method is not much more trouble than the analysis of groupings or runs, and should have greater power to detect differences in the means.

In the case of two samples of n_1 and n_2 observations ($n_1 + n_2 = N$), rank all N observations and compute the mean rank for one of the two groups—usually the smaller group, to reduce computations. This mean is tested on the assumption that its n ranks are a random sample drawn without replacement from the in-

tegers 1 to N. If S is the sum of the n ranks in one of the two samples, we compute 2S and then adjust it for discontinuity by adding or subtracting 1, whichever brings 2S closer to $n(N+1)$. The S′ in the formula below is the adjusted S, i.e. $S' = S \pm 0.5$.

Compute

$$\frac{2S' - n(N+1)}{\sqrt{n(N+1)(N-n)/3}}$$

which may be regarded as a unit normal deviate. We are interested in both tails of the distribution, so ± 1.96 gives the 5 percent significance level.

Example 4.1

Using the data of Example 3.1, twice the sum of the ranks for method A is $2S = 121$. Since $n(N+1) = 6 \times 14 = 84$, we take $2S' = 120$. Then

$$\frac{120 - 84}{\sqrt{(6)(14)(7)/3}} = 2.57,$$

which is clearly significant. (A small correction could be made for the tied ranks, but it is generally unimportant.)

This method can be extended to any number of groups. We rank all N observations and then get the sums S_i of ranks in the various groups. If n_i is the number of observations in the i-th group ($\Sigma n_i = N$), we compute

$$\frac{12\,\Sigma(S_i^2/n_i)}{N(N+1)} - 3(N+1)$$

which, if none of the n_i are too small, has approximately the χ^2 distribution with $C-1$ degrees of freedom, where C is the number of groups.

Example 4.2

Using the data of Example 3.3, for which $N = 17$, we make the following computations:

Quantity	A	B	C	Total
n	5	9	3	17 = N
S	26	94	33	153 = N(N+1)/2
S^2/n	135.2	981.7778	363	1479.978

These figures give

$$\frac{12 \times 1479.978}{17 \times 18} - 3 \times 18 = 4.038$$

as a value of χ^2 for 2 degrees of freedom. This is not significant, the probability being about 0.13. Brownlee's analysis of variance gave an F for which the probability is about 0.15.

5. NUMBER OF UPWARD AND DOWNWARD MOVEMENTS

A rough-and-ready device for deciding whether there is an upward or downward trend in a series of observations is to mark the successive differences + or —. A predominance of either direction of movement, if greater than could be expected in a random permutation of the N observations, is evidence of trend. The sign test of Section 1 cannot be used, however, because the successive differences of a random permutation are not independent. The standard deviation of the number of + (or of —) signs is not $0.5\sqrt{N-1}$ (N is the number of observations, so $N-1$ is the number of differences) but $0.2887\sqrt{N+1}$. Thus, if X is the number of + or — signs, whichever is more numerous, we calculate

$$\frac{2X - N}{\sqrt{(N+1)/3}}$$

which will be approximately normally distributed. If we are interested in detecting a trend in *either* direction, we are interested in both tails of the distribution, and 1.96 is the 5 percent significance level. If we are interested in a specified direction, we make the calculation only if movements in that direction are more numerous, and 1.645 is then the 5 percent significance level.

Example 5.1

Let us examine the error data of Table 2.1 to check the assumption that there are improvements from week to week. From the 8 weighted weekly averages we get the following sequence of signs of differences:

— — + — + — —

The minus signs do predominate, but what is the probability that if we arrange 8 different numbers at random we will find as many as 5 of the differences negative? Here we want a one-tail test. We compute

$$\frac{10 - 8}{\sqrt{3}} = 1.155.$$

This indicates a probability of about 0.12 (the exact probability, computed on the basis of the permutations of 8 numbers, is 0.1126) so it is not significant. Six minus signs among 8 observations would have been significant at the 0.6 percent level.

Example 5.2

Grant shows a control chart, taken from Taylor, on the ultimate strength of suspension insulators. The chart shows 28 points, all in control. There are 10 rises and 17 falls as we move from point to point. Applying the present test we find

$$\frac{34 - 28}{\sqrt{9.031}} = 1.93.$$

Using two tails of the normal distribution we find that this is not quite significant at the 5 percent level, the probability being 0.054. The result may, however, raise some questions. If there really is an excess of declines in the series, they must be smaller on the average than the rises, for the chart does not reveal any general fall in the level of the series and the sign test shows no significant excess of points below the process average (17 points are below, 10 above, and 1 at the average, giving a one-tail probability of 0.13).

6. GROUPING OF UPWARD AND DOWNWARD MOVEMENTS

Instead of asking about the predominant direction of movement in a series, we may ask whether there is a tendency toward runs in a given direction. That is, do the + and — signs tend to bunch more than they would in a random permutation of N observations? This can be tested on the basis of the number of groups, or runs, in the + and — signs. The grouping test of Section 3 would be invalid, however, because the successive signs in a series of differences are not independent. We count the number of groups, z, and compute

$$\frac{3z - 2N + 2.5}{\sqrt{(16N - 29)/10}}$$

which will be approximately normally distributed. We will ordinarily be interested in the negative tail of the distribution (too few groups indicate bunching) so values below — 1.645 will be significant at the 5 percent level. Should we be interested in the positive tail, the +2.5 in the formula above would be changed to —0.5.

Example 6.1

Grant gives the following series of 52 mean weights for samples of 5 cans of tomatoes. Each weight is expressed here in tenths of an ounce above 20 ounces.

29	14
20	0
14	12
20	16
15	14
19	7
8	5
0	20
15	11
16	16
2	5
5	13
5	16
17	27
11	22
18	21
16	8
8	26
19	24
12	25
7	23
15	14
26	18
13	27
11	25
1	28

The horizontal lines indicate the ends of groups of like sign in the differences. There are 32 or 34 groups, according to which way the tie goes, so we take z = 33. Then

$$\frac{99 - 104 + 2.5}{\sqrt{(16 \times 52 - 29)/10}} = -0.28.$$

Thus the grouping here is about what we expect. There is no evidence of upward and downward runs ("cycles").

7. RANK CORRELATION

One of the most widely known rough-and-ready devices is the rank correlation method of determining whether two variables are related. We replace the variables by their ranks and compute the ordinary correlation coefficient from the ranks.

TABLE 7.1

Test I	Test II	Rank I	Rank II	Squared difference in Ranks
276	14.2	1	1	0
293	15.6	5	4	1
288	16.1	3	5	4
305	15.2	7	3	16
315	14.6	9	2	49
306	21.4	8	10	4
286	19.4	2	8	36
289	18.9	4	7	9
296	18.5	6	6	0
335	20.8	10	9	1
				S = 120

Since the sums and sums of squares are known for the ranks, all we need from the data is the sum of the cross products. This we get from the sum of the squared differences in rank; for if $d = x - y$,

$$xy = \tfrac{1}{2}(x^2 + y^2 - d^2).$$

Thus all we need to know about the sample is $S = \Sigma d^2$.

To test whether the relation is more than we might expect in a chance pairing of the ranks 1 to N, we first adjust S for continuity by adding 1 if $6S < (N^3 - N)$ or subtracting 1 if $6S > (N^3 - N)$.

Thus $S' = S \pm 1$. Since $6S'$ and $N^3 - N$ are needed for the numerator of the formula below, all we need do is add or subtract 6 to the numerator as computed from the unadjusted S, in such a way as to lower the absolute value of the numerator. We then compute

$$\frac{6S' - N^3 + N}{N(N+1)\sqrt{N-1}}$$

which is approximately normally distributed. Ordinarily we are interested in both tails of the distribution, so 1.96 is the 5 percent significance level.

Example 7.1

Freeman gives the data shown in Table 7.1, taken from Jennett and Dudding, on the results of two tests of 10 light-bulb filament wires. Here $6S = 720$ and $N^3 - N = 990$, so $6S' = 726$. Then

$$\frac{726 - 990}{10 \times 11 \times \sqrt{9}} = 0.80.$$

Hence the apparent relation between the two tests is not significant. The probability of this much relation in a random pairing of the digits 1 to 10 is about 0.42; a more exact method shows 0.45.

8. QUADRANT COUNT CORRELATION

A very quick and simple test of association can be made from four simple counts.

First, we start with the largest value of one variable and, moving to successively lower values of this variable, count as many observations as we can with the second variable on the same side of its median. If the second variable lies above its median in the counted points, we mark the count plus; if below, minus.

Second, we start with the largest value of the second variable and, moving to successively lower values of the second variable, count as many points as we can with the first variable on the same side of its median, marking the count positive if the first variable lies above its median, negative if below.

Third, start with the lowest value of the first variable and, moving to successively higher values of the first variable, count as many points as possible without the second variable crossing its median, marking the count plus if the second variable lies below its median, minus if above.

Fourth, start from the lowest value of the second variable and count up as far as possible without the first variable crossing its median, marking the count positive if the first variable lies below its median, otherwise minus.

Finally, these four counts are added, taking account of their signs. The sum, called the "quadrant sum," is significant at the 5 percent level if its absolute value equals or exceeds 11, based on both tails of the distribution, or 9 based on one tail. The 5 percent significance point does not

depend on the sample size, provided the sample size is at least 8 (at least 6 for a one-tail test).

Example 8.1

The data of Example 7.1 can be used to illustrate this technique. We start with the largest observation for Test I, which is 335, and note that the corresponding value, 20.8, for Test II is above the Test II median. For the next-to-highest result for Test I, 315, we find the Test II result, 14.6, below the median; so our count stops with one observation and, since the Test II result was above the median, becomes +1. Starting with the highest value of Test II, 21.4, we find the Test I result, 306, above the Test I median. Similarly for the next-to-highest result from Test II, but not the third-to-highest. So this count stops at 2 and is positive, or +2. Then we start from the lowest Test I value, 276, and note that the Test II result, 14.2, is below the Test II median. The count stops here, at +1. Finally, starting from the lowest Test II result, 14.2, we find the Test I result, 276, below the median, but the count stops here at +1. Thus the quadrant sum is

$$S = 1 + 2 + 1 + 1 = 5$$

which is not significant. The actual probability is 0.35.

Minor adaptations of this test may be required for an odd number of pairs, or for ties.

9. REFERENCES

The numbers in parentheses indicate the examples to which the references relate. An effort has been made to cite the most practical reference for each example, indicating which parts relate specifically to the example, and also to include references to all techniques used. In addition, the sources of data used for the examples are included among the references.

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A Production Experiment Using Attribute Data

FRED ENNERSON, RALPH FLEISCHMANN, DORIS ROSENBERG

Sonotone Corporation

INTRODUCTION

One of the important components of a radio tube is a *grid*. After a grid has been wound (on a grid-lathe), it goes through a series of operations and is then inspected for the following characteristics which we measure on an attribute basis (Go-No Go):

A. Spaciness
Taper
Damage
Slant

Prior to this inspection, these grids go through the following manufacturing steps:

B-1. They are first wound on a grid-lathe. (There are several grid-lathes in use.) Immediately after winding, they are *cut* by the operator of the grid-lathe; they are then transported to an operator called a Puller.

B-2. The Puller removes some loose wire from the ends. (The loose wire is inherent in the manufacturing design.) They are then transported to a Forming-Machine.

B-3. Each Forming-Machine has its Former-Operator. After forming, the grid goes to Inspection.

B-4. The Inspector examines the grids for the characteristics listed in A.

At this point approximately 15% rejects were found.

DESIGN OF THE EXPERIMENT

In a multi-stage operation of this kind, it is difficult to estimate just how much effect the different stages may be contributing to the total rejects found at inspection; a trouble spot has to stick out like a "sore-thumb" to be recognized either by watching the individual steps in the operation or by examining the inspection data. Since the percent of rejects being found at inspection was economically important, we decided to set up a production experiment to determine how much the different production steps were contributing to this reject rate. Accordingly, an experiment was developed jointly by representatives of production, production engineering, and quality control. It included the following factors:

	P_1	P_2
F_1	L	T
F_2	T	L

Figure 1

C-1. *Grid lathes:* It was decided to remove any effect of different grid-lathes by using grids from only one lathe. (The results of this experiment cannot then be transferred automatically to other lathes.)
However, it was thought that the Tension of the lateral wire during winding on the grid-lathe might be important. Consequently, we decided to include "Loose" Tension (T_1) and "Tighter" Tension (T_2) in the experiment.

C-2. *Pullers:* The probable effect of these operators was considered important, and two of them were included in the experiment; they are designated by the symbols P_1 and P_2.

C-3. *Forming Operator:* It was judged that the operator had a more important effect than the Former itself. Consequently, two operators, F_1 and F_2 were included, but both girls operated the same Former consecutively.

C-4. *Inspection for characteristics A:* All inspection was done by the same inspector to remove any possible inspection differences.

C-5. *Design of the experiment:* Actually the design of the experiment was being established during the discussion which led to the selection of the three factors and the two "levels" of each factor. It would now be appropriate to continue in either of the following ways:

a. Perform all 8 possible combinations. The experiment would then be called a "factorial experiment"

or

b. Perform half of the possible combinations provided they are chosen according to an arrangement such as in Figure 1. This design is called a "Latin Square."

Since it was believed that the effects of the different factors were probably independent, it was decided to select the Latin Square design.

D-6. *Number of grids to include in the experiment:* The number was selected after the design of the experiment had been chosen. Since grids were moved by production in trays of 50, it was desirable to select multiples of 50 in each of

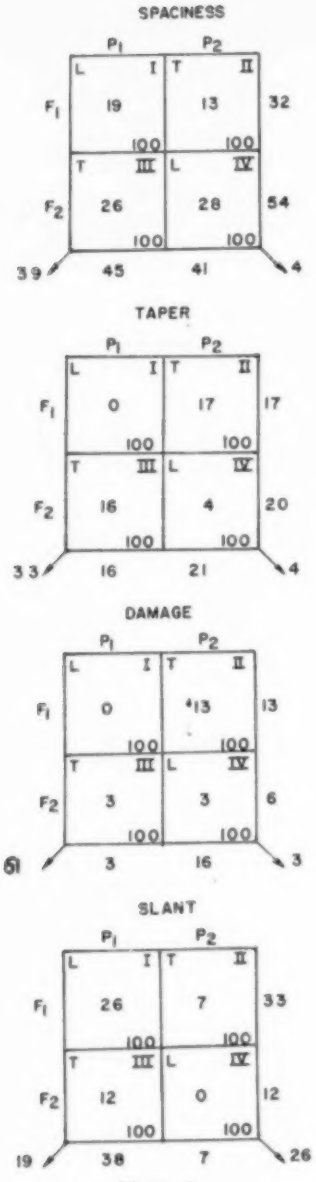
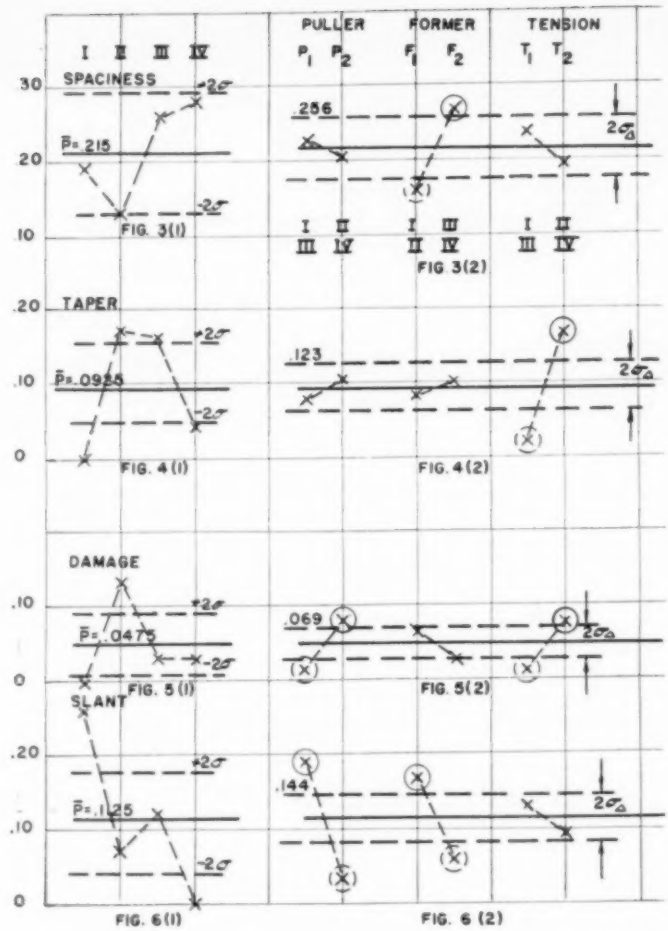


Figure 2



the four blocks. It was eventually decided to include 100 grids in each of four blocks for a total of 400 grids in the experiment. (This was somewhat arbitrary; but it allowed the entire experiment to be completed in less than a day and it did not slow down production.) We would expect to recognize a departure of as much as 2% above or below an estimated average of 5% on each of the four characteristics listed in A with about 95% assurance. (It developed that this estimate of 5% in each type of defect was not too good, but the effectiveness of the experiment was very good, nevertheless.)

In order to obtain the data corresponding to the design of the experiment, we first had 200 grids wound with loose tension (L) on our chosen grid-lathe, and then 200 grids wound with tighter tension (T). These 400 grids were "pulled" and "formed" according to the design. The number of rejects for each of the characteristics, as found at inspection, is shown in the center of the blocks in Figure 2, and the number of grids in each block is shown in the lower-right corner.

ANALYSIS OF THE DATA

In analyzing the results of experiments of this kind, we usually are more concerned with the general effect of the different factors which have been included in the experiment than we are in whether some particular combination is particularly favorable. But we often want answers to both of these possibilities.

Analysis 1

Is some one (or more) of the four combinations exceptionally good?—or bad? Or, is the variation ob-

served between the four blocks only typical of what we would expect just by chance from samples of 100 drawn from a process which averages 21% rejects? The answer is indicated by comparison with the control limits in Fig. 3(1), Fig. 4(1), Fig. 5(1), and Fig. 6(1).

For example, in Fig. 3(1), we see that the combination II is significantly good at just about the 2-sigma (2σ) level. Now in some production experiments, this much of an answer will provide enough information for production to operate. But we usually need to know "why" one combination is better, and this can be decided more easily from the figures to the right under the three headings: Puller, Former and Tension in Figures 3(2), 4(2), 5(2), and 6(2).

Analysis 2

Main effects: By combining the data within two blocks, we have the overall percent of rejects (samples of 200) as follows (Spaciness):

P_1: 45/200 = 22.5%
P_2: 41/200 = 20.5%
F_1: 32/200 = 16%
F_2: 54/200 = 27%
Loose: 47/200 = 23.5%
Tight: 39/200 = 19.5%

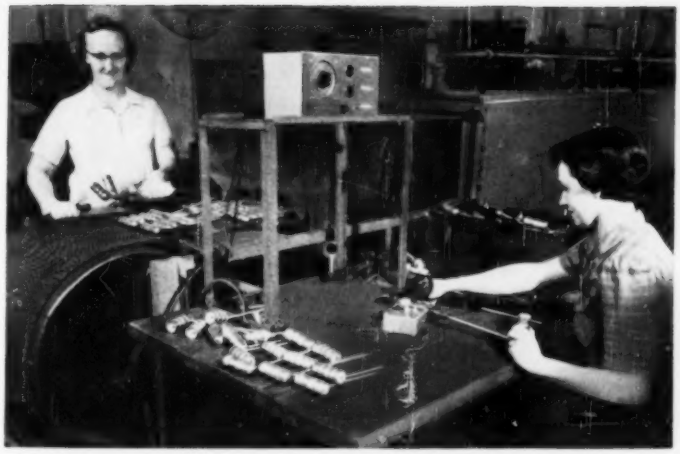
These have been indicated in Fig. 3(2). Dotted lines have been drawn above and below the average, $\bar{p} = .215$; the distance between these dotted lines has been designated by the symbol $2\sigma_{\bar{X}}$.* Now if a pair of points, such as F_1 and F_2, are outside these $2\sigma_{\bar{X}}$ lines, then there is only about one chance in twenty that the operations which produced these results are essentially the same.

We cannot predict that the difference in effect of operators F_1 and F_2 will be exactly the 10% or 11% difference found in this experiment. But we can predict (with about 95% confidence) that the Former Operator F_1 will produce fewer defects than will F_2. The average difference over a period of time (assuming no fundamental change in their performance) may be more or less than the observed difference in this experiment.

CONCLUSIONS

By examining the four figures on the right of the control chart sheet, we see where to place our emphasis for improving the operation; it should be somewhat as follows:

*See Note at end of paper.



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GENERAL ELECTRIC

687-88

Tension: A Loose-Tension on the grid lathe is preferable to a Tight-Tension with respect both to Taper and Damage. We have no real reason to assert whether it does or does not affect the other characteristics. See Figures 4(2) and 5(2).

Former-Operators: These operators have an effect on Spaciness and Slant. Operator F_2 needs instruction with respect to Spaciness; and Operator F_1 with respect to Slant. See Figures 3(2) and 6(2).

Pullers: Again, one girl is better on one characteristic and worse on the other. Operator P_1 is a little more careful with respect to Damage; but she is ruining too many for Slant. See Figures 5(2) and 6(2).

It may be that there are other significant effects on these three factors; but if so, a larger number of samples in each block would be needed to detect such significance. However, this experiment has already provided enough information to make substantial improvements in the processing of the grids.

NOTE

The symbol σ_Δ represents "sigma of the difference" of two percentages. It is equal to:

$$\sigma_\Delta = \sqrt{2}\,\sigma_p = \sqrt{2}\,\sqrt{\bar{p}(1-\bar{p})/n}$$

In Fig. 3(2), we have $\bar{p} = .215$, and $n = 200$. Then,

$$\sigma_p = \sqrt{(.215)(.785)/200} = .029,$$

and

$$\sigma_\Delta = \sqrt{2}(.029) = .041.$$

Then the distance between lines drawn at

$$\bar{p} + \sigma_\Delta = .255 \text{ and } \bar{p} - \sigma_\Delta = .174$$

will be $2\sigma_\Delta$, and we have evidence (with 95.4% assurance) that the pair of points which have been circled do not represent just chance variation of a process with $\bar{p} = .215$. That is, we have evidence that the Former Operator, F_1, is doing a fundamentally better job than the Operator, F_2. At the same time, we do not have evidence (at least at the 2σ level) to indicate that the difference between the two tensions, in Fig. 3(2), is anything except chance variation.

A more formal statement of the experiment might be the following: We make the hypothesis that there is no difference in the effect of F_1 and F_2 on Spaciness. Then we compute σ_Δ, and find that the difference between their effects is slightly more than $2\sigma_\Delta$. This is not consistent (at the 95% level) with our hypothesis. The choice of the level of desired assurance rests with those responsible for the improvement of the situation.

Bibliography

JOSEPH MOVSHIN, Editor

Assisted by the Editorial Committee, St. Louis Section, ASQC

On matters concerning the Bibliography Department, send correspondence, suggestions, and contributions to: Mr. Joseph Movshin, 9220 Old Bonhomme Road, St. Louis 24, Mo.

BIBLIOGRAPHICAL

BIBLIOGRAPHY on the Use of IBM Machines in Science, Statistics and Education.
Published by International Business Machines Corporation, Jan. 1950.

This bibliography contains about 360 references on the solution of mathematical and statistical problems through the use of various business and calculating machines. The references are listed under three headings: A, Science; B, Statistics; C, Education and Test Scoring. A subject index is included. This is an excellent source of references for information in the fields covered.

APPLICATION—CHEMICAL INDUSTRY

STATISTICAL METHODS IN CHEMICAL PRODUCTION
Symposium at 119th Meeting of the American Chemical Society, Boston, Mass.
(Industrial & Engineering Chemistry, v. 43, n. 9, Sept. 1951)

The following articles are included in this group. These contain excellent technical information on the use of statistical methods.

"A NEW SCIENCE OF TROUBLE SHOOTING," L. A. Seder, Gillette Safety Razor Co., page 2053.

"LOCATING SOURCES OF VARIABILITY IN A PROCESS," W. J. Youden, National Bureau of Standards, Washington, D.C., page 2059.

"APPLICATION OF TEST FOR RANDOMNESS," C. A. Bennett, General Electric Co., Richland, Washington, page 2063.

"CORRELATION METHODS APPLIED TO PRODUCTION PROCESS DATA," K. A. Brownlee, Squibb Institute for Medical Research, New Brunswick, N. J., page 2068.

"STATISTICAL TRAINING FOR CHEMISTS," H. M. Smallwood, U.S. Rubber Co., Passaic, N. J., page 2071.

APPLICATION—FOOD INDUSTRY

INSTRUMENTS FOR OBJECTIVE MEASUREMENT OF QUALITY CONTROL FACTORS IN PROCESSED FOOD PRODUCTS, B. W. Clarke, Crosse & Blackwell Co., Baltimore, Md.

(Food Technology, v. 5, n. 10, Oct. 1951, p. 414)

While quality control is now used in the food processing industry, it could be more widespread if instruments were available to evaluate important characteristics of the food products. In this article, the author enumerates some of the factors for which convenient instruments are not available. These include measurement of pH; consistency of such items as soup, jellies and catsup; texture of fruits to determine their suitability for canning or other processing; measurement of color and others.

APPLICATION—METALLURGICAL INDUSTRY

EFFECT OF SINTER ON BLAST FURNACE PRODUCTION, W. E. Marshall, American Iron and Steel Institute.
(Metal Progress, Oct. 1951, p. 162)

A method is submitted for determining the effect of sinter on blast furnace production, with the use of statistical analysis of daily operating data. For this purpose, a statistical study was made, using 1000 daily values from a blast furnace having a hearth diameter of 18 ft. and a capacity of 800 tons per day. The study was made by analyzing the two variables, blowing rate and efficiency, and their related factors. The influence of sinter on operating characteristics is shown graphically in five separate figures and this article explains what these figures indicate.

APPLICATION—METAL WORKING

HOW PLANT ENGINEERS SHOULD UTILIZE QUALITY CONTROL, E. L. Fay, Quality Control Adviser, Deere & Co., Moline, Illinois.
(Plant Engineering, v. 5, n. 12, Dec. 1951, p. 67)

After a general discussion of the advantages and purposes of Quality Control by Statistical Methods, a detailed case study on the use of the control chart is given. The operation is the grinding of the thickness of a spacer ring. The sampling procedure is also discussed.

STATISTICAL QUALITY CONTROL OF METAL-WORKING OPERATIONS, Lester F. Spencer.
Part 3. Control Charts for Inspection by Attributes.
(Steel Processing, v. 37, no. 10, Oct. 1951, p. 506)

Three charts are discussed: (1) The chart for fraction defective, (2) the chart for number of defectives, and (3) the chart for number of defects.

Formulas, tables and charts are given.

Part 4. Conclusion.
(Steel Processing, v. 37, n. 11, Nov. 1951, p. 567)

The last article of this series takes up organization for quality control and some of the ways to

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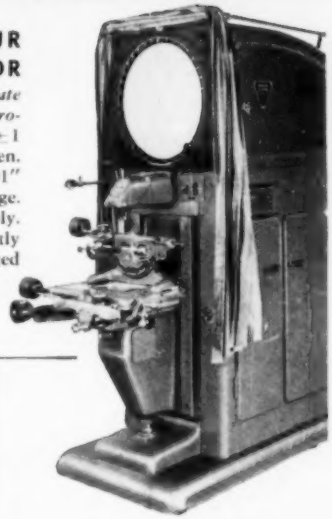

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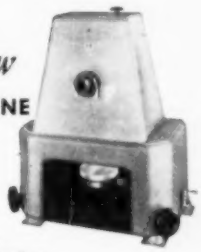

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justify quality control methods to management.

Parts 1 & 2 of this series reported in the Jan. 1952 IQC Bibliography.

APPLICATION—MISCELLANEOUS

APPLICATION OF STATISTICAL TECHNIQUES IN TIME STUDY, George D. Wilkinson, George D. Wilkinson & Co., Oceanport, N. J.
(Mechanical Engineering, v. 73, n. 11, Nov. 1951, p. 906)

In the opinion of the author, time study needs to avail itself of statistical techniques to re-establish its validity as a "scientific method." The problem of the number of readings in a time study to give an average value within 5% of the true value is considered. A simple formula and table giving probabilities that the averages of individual samples will differ from the true mean by more than 5% are given in terms of sample size. Examples of the use of this formula and table are included.

RECENT PROGRESS IN STATISTICAL QUALITY CONTROL IN THE TEXTILE INDUSTRY, N. L. Enrick, Werner Textile Consultants.
(Textile Age, Sept. 1951, p. 48)

The textile industry has found increasing use for statistical quality control techniques during the past few years. Control charts, sampling plans, correlation, and analysis of variance are four distinct categories into which the principal statistical applications fall. These are briefly discussed.

A SHARP TOOL FOR INDUSTRIAL ENGINEERS, John M. Allderige, Industrial Engineering Division, Eastman Kodak Co.
(Advanced Management, v. XVI, Sept. 1951, p. 12)

A discussion of how the industrial engineer may well apply some of the techniques of the quality control man in analyzing the nature of data collected from samples of an industrial process. Particular emphasis is placed upon precision of estimates based upon samples, and the validity of taking action from these data. Applications are mentioned to inventory control, distribution of models going through a production line, using

the control chart, and confidence intervals.

ENGINEERING & EXPERIMENTS

CHI-SQUARE TEST, Wayne A. Ring, Development Engineer, & Edward C. Varnum, Mathematician, Barber-Coleman Co., Rockford, Illinois.

(Machine Design, v. 23, n. 11, Nov. 1951, p. 115)

Chi-square is used as a test to compare expected machine performance with actual. This is done in terms of a limited arbitrary grading of production. Examples of calculation are given. An interesting nomogram for the probability associated with values of chi-square is given.

MANAGEMENT AND PERSONNEL

CONTROLLING QUALITY BY A DIFFERENT PROCESS

(Production Engineering & Management, v. 28, n. 6, Dec. 1951, p. 54)

This article discusses the quality control approach used at Graflex, Inc. Under this plan all responsibility for quality, and the evaluation of quality lies with the production supervisor. Each supervisor has his own inspectors and gage cribs. All production work is on incentive and inspection allowances are made. After setup the operator then assumes responsibility for the quality produced. Large savings and good quality are reported as a result of this system.

DO YOU NEED A QUALITY CONTROL TROUBLE SHOOTER?, George W. Slomin, Process Engineer, Hughes Aircraft Co., Culver City, California.

(The Iron Age, Sept. 1951, p. 114)

How to create a one-man clinic if you cannot afford a quality control staff? Requirements: About 5 years of mechanical engineering experience and at least 2 years of practical shop experience; a working knowledge of chemical and electrical engineering; ability to familiarize himself quickly with all types of processing equipment, tools and control devices; an excellent knowledge of statistical methods of analysis and a good knowledge of mathe-

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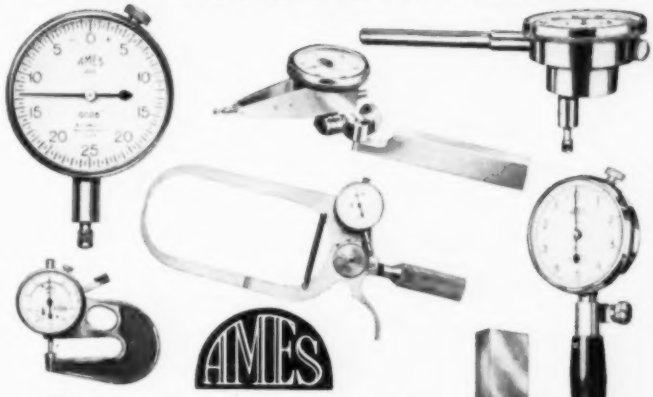

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MISCELLANEOUS

THE EXPLICANDUM OF THE CLASSICAL CONCEPT OF PROBABILITY, Norman M. Martin.

(Philosophy of Science, v. 18, n. 1, Jan. 1951, p. 70)

A historical review of the philosophical concepts of probability is made. From this, the modern philosophical implications in the concept of probability are developed.

QUALITY REPORTING

USING STATISTICS IN INSPECTION, Carl V. Slather, Chief Inspector, Tractor and Unit Engine Division, Minneapolis Moline Co.

(Modern Machine Shop, v. 24, n. 6, Nov. 1951, p. 140)

This article discusses some of the ways by which an inspection department, using statistics, can furnish useful information to other departments, such as Engineering, Sales, Purchasing, Methods, Shop Foremen, Machine Maintenance and Foundry. Control charts and Histograms illustrate the examples given.

THEORY & APPLICATION—GENERAL

STATISTICS IN PRODUCTION AND INSPECTION, Edwin G. Olds, Carnegie Institute of Tech.

(Journal of the American Statistical Association v. 46, Sept. 1951, p. 297)

A review of the broad fields of statistical quality control theory, history, and application is presented. This is used as background information to discuss three questions regarding the future directions of statistical methods. These questions are:
1) "What contribution can the statistician make to greater and more effective utilization of present statistical methods in industry?"
2) "What part can the statistician play in developing new statistical methods and in making them readily available?"
3) "How can the quality control engineer get the maximum benefit from the work of the statistician?"

The tentative answers suggest the need for close co-operation between the engineer and statistician to increase the use of statistics in production and inspection.

QUALITY CONTROL, Theodore H. Brown, Professor of Business Statistics, Harvard Business School.

(Harvard Business Review, v. 29, n. 6, Nov. 1951, p. 69)

The basic concepts of quality control, frequency distributions, control chart techniques, control of attributes, and acceptance sampling, are presented. In addition, the author discusses the place of statistical methods in research and development, the effects on personnel, costs and savings, training methods, and a note on the future of statistical methods in industry.

STATISTICS

TEST FOR THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS IN TWO NORMAL POPULATIONS HAVING UNEQUAL VARIANCE, D.G. C. Gronow.

(Biometrika, v. 38, June 1951, p. 252)

ON THE VARIANCE OF ESTIMATES OF THE STANDARD DEVIATION AND VARIANCE, W. D. Evans.

(American Statistical Association, Journal, v. 46, June 1951, p. 220)

ESTIMATING LINEAR RESTRICTIONS ON REGRESSION COEFFICIENTS FOR MULTIVARIATE NORMAL DISTRIBUTIONS, W. T. Anderson.

(Annals of Mathematical Statistics, v. 22, Sept. 1951, p. 327)

PROBABILITY OF A CORRECT RESULT WITH A CERTAIN ROUNDING OFF PROCEDURE, W. S. Loud.

(American Mathematical Society, Proceedings, v. 2, June 1951, p. 440)

Book Reviews

A. C. Cohen, Jr., *Editor*

Correspondence and suggestions concerning book reviews should be sent to:
Professor A. C. Cohen, Jr.
Department of Mathematics
University of Georgia
Athens, Ga.

MATHEMATICS OF STATISTICS, PART TWO

J. F. Kenney and E. S. Keeping; D. Van Nostrand Company, Inc., New York, 1951, 429 + xiii pages. Review by Allen T. Craig, Department of Mathematics, University of Iowa.

This book is an enlarged and revised edition of the popular Mathematics of Statistics, Part Two (1939), by the first named author. It is intended primarily to serve as a text for students of mathematical statistics at the intermediate level, but we believe the book to be useful to those who make serious use of statistical methods in industry.

Chapter I, on probability, has been essentially rewritten and expanded considerably so as to include several approaches to a theory of probability.

The second chapter treats the binomial, the Poisson, the normal, the Cauchy, and the hypergeometric distributions. The concepts of mathematical expectation and moments are introduced. There then follows a chapter on some properties of Beta and Gamma Functions and a derivation of Stirling's asymptotic formula for factorials.

Chapter IV introduces joint distributions in several variables and the important concepts of moment-generating functions, characteristic functions, cumulants, and the Central Limit Theorem. In Chapter V, there are taken up some additional properties of Beta and Gamma distributions, systems of frequency curves, curve fitting, and the Chi-square test. The following two chapters are devoted to problems of sampling theory with particular reference to the arithmetic mean and the variance, the latter restricted of course to sampling from a normal distribution. The "Student" and Fisher distributions are then found and various questions about confidence limits for parameters are considered in detail. Confidence limits

for parameters in problems of linear regression and correlation and a study of contingency are dealt with in Chapter VIII.

The analysis of variance and covariance together with an introduction to experimental design are presented in Chapter IX. Quality Control Engineers who are making use of these techniques might find pages 249-254 quite helpful. In Chapter X there are handled various aspects of the method of least squares and the distribution of the sum of squares of residuals. The authors provide the reader with the elegant methods of matrix algebra for use with some of the problems of least squares.

Multiple and partial correlation, curvilinear regression, and discriminant functions are the subjects of Chapter XI. The last chapter is devoted to a survey of a number of topics of statistical inference. In regular cases of estimation, the basic ideas of efficient and sufficient estimates are presented; properties of maximum likelihood estimates are discussed; a more general formulation of the theory of confidence intervals is set forth; the theory of tests of hypotheses and the concept of the power of a test are included; and the chapter closes with an introduction to sequential tests of hypotheses and tolerance limits for statistical populations.

In a brief report of this kind, it is not possible to dwell on the multiplicity of ideas involved. Our chief purpose has been that of bringing to the attention of readers of this journal the general nature, content, and organization of the text. We recommend it for consideration.

AMERICAN SOCIETY NEWS

NOMINATING COMMITTEE REPORT, 1952

The Nominating Committee has completed its work in selecting nominees for Society offices in 1952-53. The official report of the committee is reproduced herewith. All members of the Nominating Committee are members of the Board of Directors as provided in the Constitution.

January 7, 1952

Mr. Alfred L. Davis
Executive Secretary, ASQC
New York, New York

Dear Mr. Davis:

As provided in the Constitution of the Society, we—the members of the Nominating Committee for 1952-53—do hereby report the following as our nominees unanimously chosen for the Society offices in 1952-53:

For President: Simon Collier
Metropolitan Section

For Vice-Presidents: Raymond S. Saddoris, Milwaukee Section
Julian H. Toulouse
Toledo Section
Arthur Bender
Indianapolis Section

For Executive Secretary: Edward B. Haden, Philadelphia Section

For Treasurer: Paul A. Robert
Southern Tier Section

Each of the above nominees has expressed to our Chairman his willingness to accept if elected to the office for which we have nominated him.

Respectfully submitted,
Enoch B. Ferrell
Ralph A. Hefner
Wyatt H. Lewis
A. C. Richmond
Dorian Shainin
I. Glenn Stevenson
Ralph E. Wareham, *Chairman*

SHEWHART MEDAL FUND

Readers will recall that the President has initiated a drive to build up the depleted Shewhart Medal Fund to a point where the medal presentation is a self-sustaining act. The November, 1951 issue of IQC carried a news item on this subject. It is with great pleasure that we announce the following contributions to date:

Cleveland Section	$ 75.00
Metropolitan Section	50.00
Rhode Island Section	5.00
New England Region	100.00

It is our sincere hope that others will recognize the merit of this fund and wish to participate in its development.

OUR INCREASING FAMILY

Newest Section to be recognized is the Dallas-Fort Worth (Texas) Section as the fifty-fifth Section of the Society. Officers of this Section are as follows:

National Director:
James C. McKelvain, Director of Quality Control
Texas Engineering & Mfg. Co., Inc.
Dallas, Texas

Chairman:
James L. Coburn, Supervisor of Quality Control
Consolidated Vultee Aircraft Corp.
Ft. Worth, Texas

Vice Chairman:
Clarence C. Wilson, Director of Quality Control
Intercontinental Mfg. Co., Inc.
Garland, Texas

Secretary:
Herbert B. Epstein, Supervisor of Quality Control
Chance Vought Aircraft
Dallas, Texas

Treasurer:
Carl Bentley, Assistant Chief Inspector
Texas Engineering & Mfg. Co., Inc.
Dallas, Texas

This oil country Section "came in" with 175 members. Texas always does things in a big way.

The fifty-sixth Section of our ever-increasing family is San Diego, California (is there more than one San Diego), which was recognized on February 9, 1952. Being from another area with quite a reputation for large accomplishments, this Section starts out with 111 members. Officers are as follows:

National Director:
I. Dagan, Chief Inspector
Rohr Aircraft Corporation
Chula Vista, California

Chairman:
Earl G. Smith, Quality Methods Supervisor
Solar Aircraft Company
San Diego, California

Vice Chairman:
Leonard B. Allen, Quality Control Manager
Solar Aircraft Company
San Diego, California

Secretary:
Bern R. Swarts, Chief of Process Control
Consolidated Vultee Aircraft Corp.
San Diego, California

Treasurer:
Charles D. Wilcox, Salvage Engineer
Ryan Aeronautical Company
San Diego, California

The Society is happy to extend a warm welcome to these two new Sections and the new members they bring into the Society. The hope is expressed that they will enter actively into all Society activities.

ANNUAL MEETING OF THE SOCIETY

Pursuant to recent custom, the Annual Business Meeting of the Society will be held during the National Convention at Syracuse. The meeting will be held in the third floor meeting room of the Onondaga Memorial Building (site of Convention) at 4:10 P.M., on Thursday, May 22, 1952. Society members will be afforded an opportunity to hear the official reports of the Officers, Committee Chairmen, etc., for the fiscal year 1951-52, and are urged to attend.

BOARD OF DIRECTORS MEETING

All Directors of the Society are strongly urged to plan now to attend the Annual Board Meeting which will be held at the time of the convention. This very important meeting is being called for 2:00 P.M., on Saturday, May 24, 1952, and will be held at the Onondaga Hotel. A Directors' Banquet will follow the meeting, so be sure to arrange your transportation plans accordingly.

CONSTITUTIONAL CHANGES TO BE VOTED

Members will recall that at the time of the 1951 voting for Officers, they voted favorably on "approval of intent" to alter our Constitution to permit "more than one Vice President, the exact number to be at the discretion of the Board."

In accordance with this intent, the Nominating Committee was instructed by the Board to provide for three Vice Presidents for the year 1952-53, and has so acted, as will be noted from the report of this Committee.

The Committee on Constitution and By-Laws has prepared the exact wording of all the Constitutional changes necessary to comply with this mandate. These have been reviewed and endorsed by the Executive Committee, and the Board of Directors has subsequently voted their referral to the membership for adoption. Accordingly, included with the ballot for Officers, which will be sent to all members in April, will be an official ballot for voting on these Constitutional changes. Thus, the actual amendments will have been officially approved by the membership before the Vice Presidents assume office.

Included at this same time will be other amendments considered advisable to clarify our Constitution. These have all been carefully reviewed by, and bear the endorsement of, the Board of Directors.

CONSULTING SERVICES

Responsibility of the American Society for Quality Control, Inc., for Consulting Services advertising is limited to certification that advertisers hold the grade of membership in the Society stated in their advertisements. Qualification requirements for the several grades of membership are set forth in the Constitution of the Society.

Management Controls

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References and Literature on Request

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RALPH E. WAREHAM
Fellow, ASQC

122 Orchard Ridge
Chappaqua, New York

Telephone
Chappaqua 1-0715

SQC COURSES

Basic Courses to acquaint industrial personnel with the techniques for putting SQC to work.

University of Illinois, Urbana, Ill., April 14-24, 1952. For information, write to

J. A. Henry
Department of Mechanical Engineering
University of Illinois
Urbana, Illinois.

University of Colorado, Boulder, Colo., June 17-27, 1952. For information, write to

John F. Wagner
College of Engineering
University of Colorado
Boulder, Colorado.

An Advanced Course for further training of personnel with some previous instruction or practical experience in SQC.

Purdue University, Lafayette, Ind., June 4-12, 1952. For information, write to

Irving W. Burr
Statistical Laboratory
Purdue University
Lafayette, Indiana.

POSITIONS WANTED

Address all replies to box number references to: American Society for Quality Control, Room 5036, 70 East 45th Street, New York 17, N.Y.

QUALITY CONTROL ENGINEER. Age 37. Six years Quality Control experience in the electrical, mechanical, and chemical industries. Engineering and statistical degrees. Nationally known; many speeches and publications. Qualified for manager of Inspection and Quality Control or as engineer in large inspection, test, or research organization. Salary range: $10,000. Please reply to 8C1 at above address.

QUALITY CONTROL MANAGER. Age 43. Eleven years experience as Chief Inspector and Quality Control Manager in automotive and aircraft multi-plant operations. Send reply to 8E1 at above address.

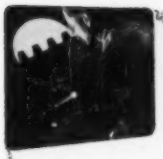
GRADUATE CHEMIST—B.Sc.; Canadian; age 24. Experienced in SQC and other applications of statistical methods. Background of research, development, and control on starch, adhesives, fats and oils, paint, etc. Seeks responsible position in QC department or QC laboratory. Please reply to 8E2 at above address.

GRADUATE E. E. ENGINEER — 13 years experience industrial engineering work with four years heading up Quality Control Department. At present manager of Quality Control, planning and analyzing new product research and design, process control, sampling methods and manufacturing control chart technique. Thorough background in organizing, training and supervising employees. Experienced in correlating quality concept between Sales, Engineering Design, Manufacturer and Customer. Will relocate. Write to 8E3 at above address.

POSITIONS AVAILABLE

Address all replies to box number references to: American Society for Quality Control, Room 5036, 70 East 45th Street, New York 17, N.Y.

QUALITY CONTROL SUPERVISOR AND ENGINEERS—Must have theoretical background, experience in application of statistical methods to mechanical parts manufacture, and preferably a knowledge of electronic equipment manufacture. Will work in beautiful new plant (350,000 square feet) to be completed this year in Northeastern Pennsylvania. Please reply to 8L1 at above address.



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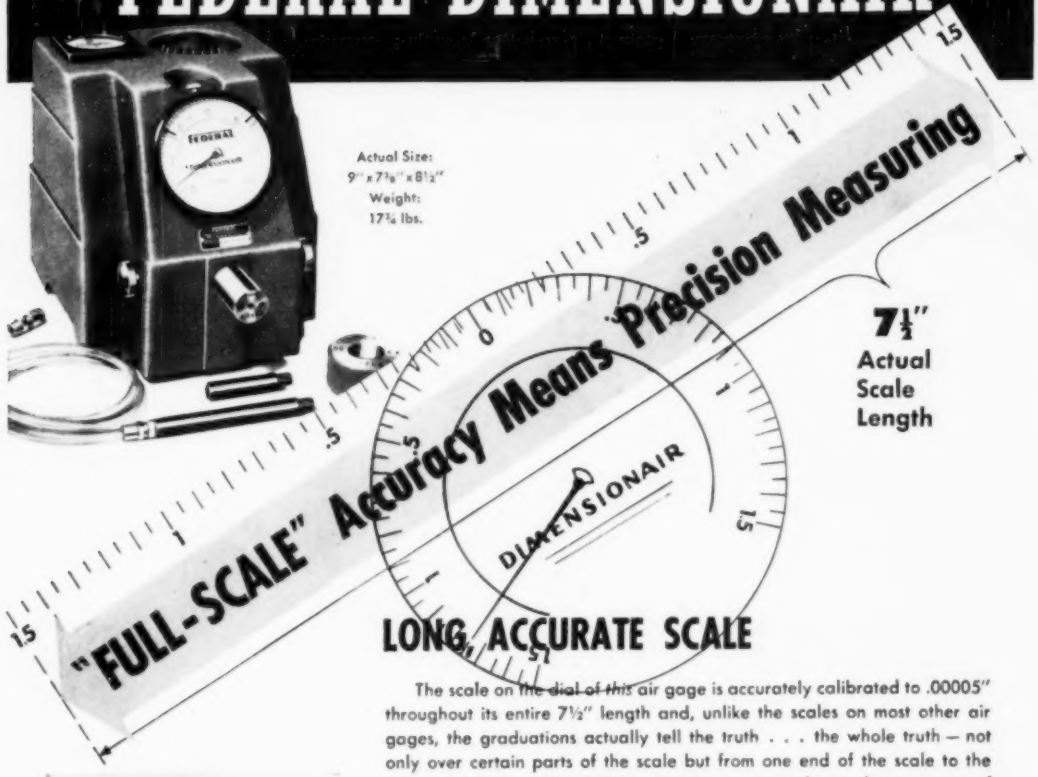
FEDERAL DIMENSIONAIR

Actual Size:
9" x 7⅞" x 8½"
Weight:
17¼ lbs.



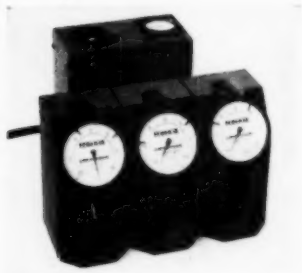
7½" Actual Scale Length

LONG, ACCURATE SCALE

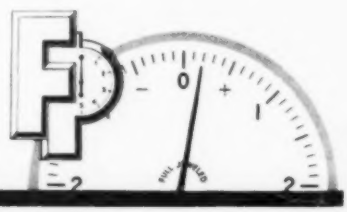
The scale on ~~the dial of this~~ air gage is accurately calibrated to .00005" throughout its entire 7½" length and, unlike the scales on most other air gages, the graduations actually tell the truth . . . the whole truth — not only over certain parts of the scale but from one end of the scale to the other. With the Federal Dimensionair you can rely on the accuracy of readings *anywhere* on the scale and work to close limits within a wide tolerance zone.

The Federal Dimensionair has many other important features: The long operating range of .003" with 2500 to 1 magnification provides clearance for exploring irregularly shaped or tapered holes and permits the *same* plug to be used on *both* rough and finished dimension. This clearance also means longer plug wear. The Dimensionair is easily set with only one master due to the accuracy of our scale and it remains stable for long periods.

Ask our nearest representative to show you this air gage which sets new standards in better, more positive air gaging, or write to us for complete information and prices. Federal Products Corporation, 1153 Eddy Street, Providence 1, Rhode Island.



A Triple Gage set up with remote regulator control. Any number may be used according to number of dimensions to be gaged simultaneously.

FEDERAL

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